Pacific Coast Society of Prosthodontists Meeting, Timberline Lodge, Government Camp, Oregon, July 31 to August 2, 1958.

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THE JOURNAL OF PROSTHETIC DENTISTRY

VOLUME 8 JULY, 1958 NUMBER 4

COMPLETE DENTURES
REMOVABLE PARTIAL DENTURES
FIXED PARTIAL DENTURES
OPERATIVE DENTISTRY

Official Publication of

THE ACADEMY OF DENTURE PROSTHETICS
THE AMERICAN DENTURE SOCIETY
THE PACIFIC COAST SOCIETY OF PROSTHODONTISTS
THE AMERICAN ACADEMY OF RESTORATIVE DENTISTRY
THE AMERICAN ACADEMY OF CROWN AND BRIDGE PROSTHODONTICS
THE GREATER NEW YORK ACADEMY OF PROSTHODONTICS

PUBLISHED BY
THE C. V. MOSBY COMPANY, 3207 WASHINGTON BLVD., ST. LOUIS 3, U.S.A.

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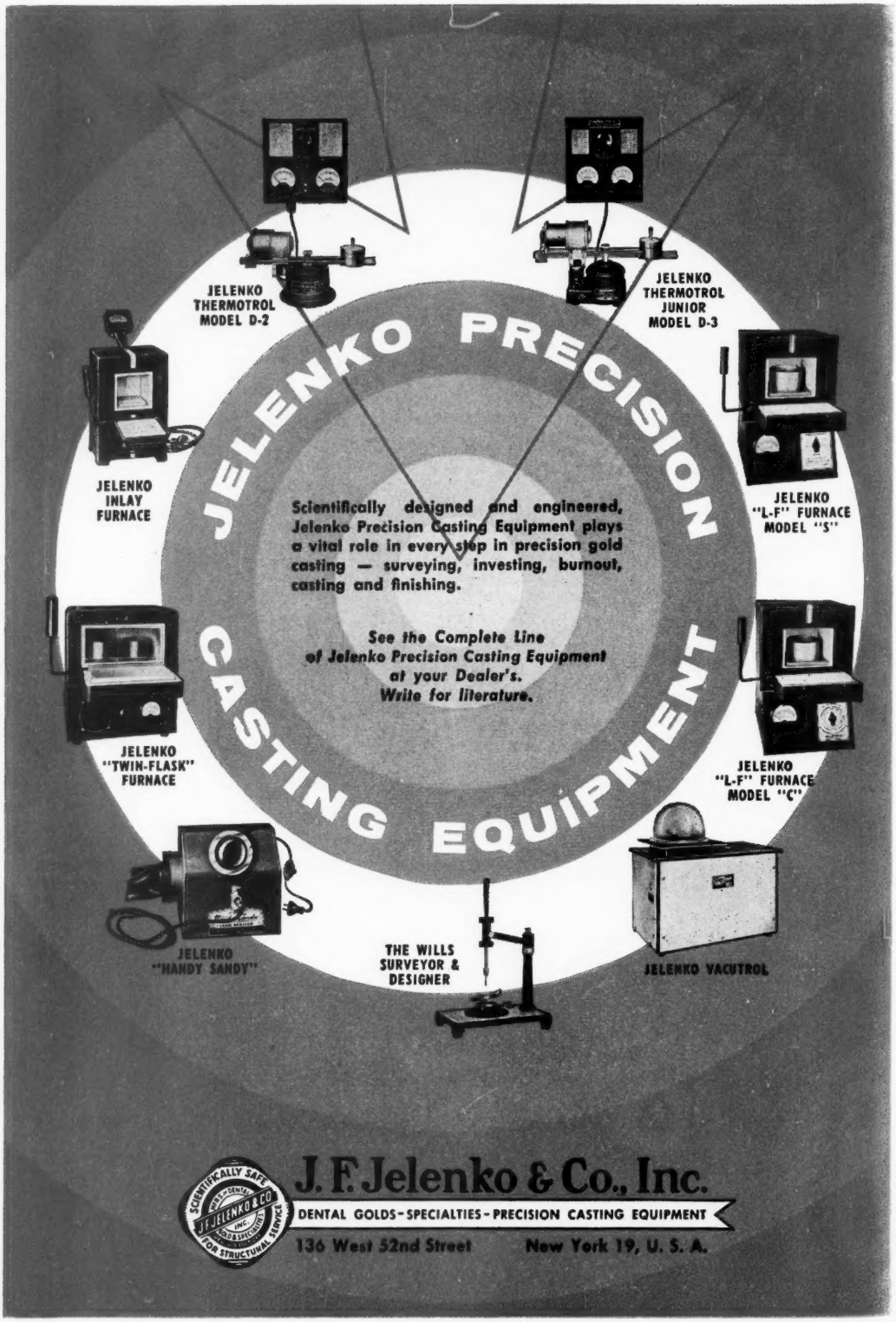
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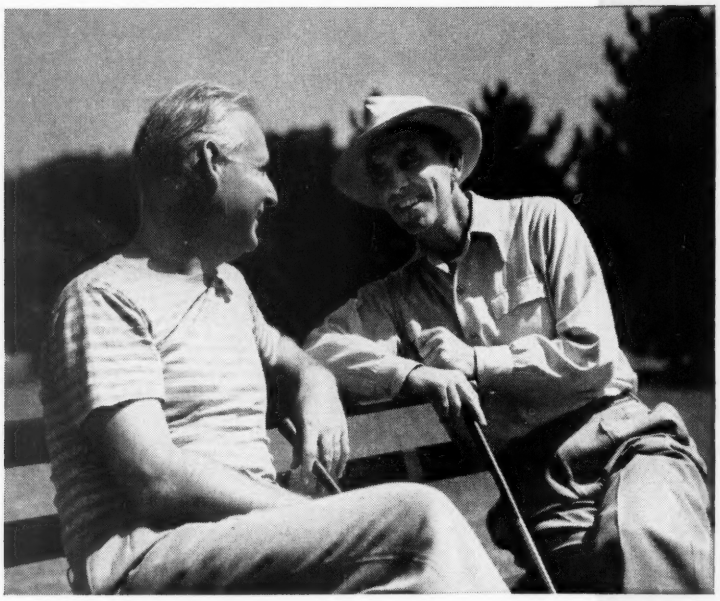

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Vol. 8, No. 4, July, 1958. Journal of Prosthetic Dentistry is published by the C. V. Mosby Company, 3207 Washington Blvd., St. Louis 3, Mo. Subscription rates: United States and Its Possessions $12.00, Students $6.00: Canada, Latin-America, and Spain $12.50, Students $6.50; Other Countries $13.00, Students $7.00. Single copies, $2.50 postpaid. Entered as second-class matter March 13, 1951 at the Post Office at St. Louis, Missouri, under the Act of March 3, 1879. Additional entry authorized at Jefferson City, Missouri. Printed in the U. S. A.

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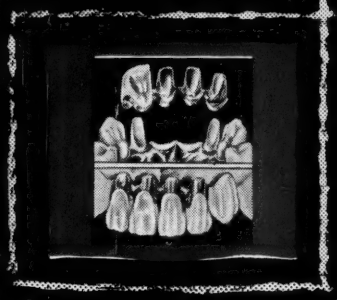

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THROUGH THE EYES OF THE EDITOR

John P. Frush and Roland D. Fisher discuss their concepts of esthetics of dentures and describe their techniques for expressing beauty and harmony in prosthodontics. Their basic concept relates the appearance of the denture in the mouth to the physical and psychologic qualities of the patient. They have coined some new words to express the relationship between the appearance and function of dentures. There may be some question about the *need* for a word such as "dynesthetic" since the term "esthetic" means more than a "still life" as it applies to denture patients. Denture "esthetics" implies appearance in function when a dentist thinks of dentures in a patient's mouth. They suggest a different approach to tooth color selection which is worthy of consideration. They describe in detail various modifications of tooth positioning which will add flexibility to the over-all effect on the appearance of the dentures. These modifications may be used to avoid the deadly monotony or similarity of tooth arrangement on any given dentist's dentures. The all too common fault of dentures is the similarity of their appearance which results from the re-use of an arrangement which was particularly pleasing in another patient's mouth. There must be variations in tooth selection and arrangement from patient to patient.

Sidney I. Silverman discusses the various psychologic considerations involved with denture service. He shows the relationships between the psychologic factors and the physical problems of denture service. On this basis it is not too difficult to understand the complaints and difficulties of denture patients. An understanding of these psychologic considerations will benefit both the patient and the dentist.

Henry A. Collett discusses various oral lesions that are associated with dentures. He recognizes that some of these lesions are caused by a denture, that some are aggravated by a denture, and that some are coincidental because they are due to general systemic conditions. A differential diagnosis is essential, and he suggests that dentists should recognize and differentiate between these lesions, but that dentists should attempt to treat only those lesions directly related to the dental condition or restoration. The general systemic conditions should be treated by physicians, but the dentist can and should recognize lesions and make sure that the patient gets the treatment he needs.

William L. McCracken suggests a new method for controlling the pressures applied on lower impression trays while the final impression is made. In his comparison of currently used impression materials and methods, he points out the factors that influence the position of the soft tissues when the impression material sets. His procedure eliminates most of the external distorting factors, such as the presence of the dentist's fingers in the mouth. The pressures applied can be regulated in amount, and they can be equally distributed by this method if it is

properly applied. The method does not eliminate the necessity for having an accurately formed and planned tray. The tongue could overtrim the lingual borders of the impression if the tray did not prevent the tongue from rubbing against it. The method he suggests has intriguing possibilities.

Oliver C. Applegate discusses the role of removable partial dentures in the practice of dentistry. He anticipates an increase in the need for this service in the next twenty-five years because of the improvements in techniques of operative and periodontal therapy and because of the increasing awareness of the public regarding its possibilities. This situation imposes an additional responsibility upon the profession to prepare itself adequately for rendering partial denture service. He discusses the fundamental considerations involved in diagnosis and design and suggests means whereby the supporting tissues can be protected so they will provide for longer service of these restorations. One of these methods involves planned reconditioning of the edentulous areas.

D. J. Neill discusses the problems involved in removable partial dentures with free-end denture bases. These problems become more acute if the partial denture is opposed by a complete denture. He considers each of the undesirable conditions which may result from the wearing of this type of restoration and makes recommendations designed to avoid the difficulties. One of his recommendations involves the use of stressbreakers, and he describes designs which allow independent movement of the denture bases as one possible solution.

Frank D. Dunworth discusses the use of porcelain fused to gold and reports the results of his clinical use of this combination of materials for crowns and fixed partial dentures. Esthetics seems to be one of the more serious problems, but more research will provide the solution. He lists the indications for the use of these materials, and this points up the need for adequate diagnosis before the materials are chosen. His results indicate that, when properly used in the right places, porcelain fused to gold can produce satisfactory restorations.

Earl Stone suggests that time can be saved and patient discomfort can be minimized if periodontal treatment is carried out concurrently with the preparation of teeth for crowns. If gingivectomy is indicated, it can be accomplished at the same appointment when the tooth is prepared. The temporary tooth coverage can be used while healing occurs; this allows additional time for observing the reactions of the tooth before the permanent appliance is cemented in place.

Daniel Isaacson reports on his clinical study of the Bennett movement. His methods were different from those used by Bennett, but he was able to demonstrate a lateral shift of the mandible which occurred simultaneously with a lateral rotation of the mandible. This side shift *could* be responsible for rotations of dentures on their foundations if the teeth were not arranged to be in harmony with this movement. It is significant that considerable variation in the magnitude and direction of the side shift was noted. The tracings themselves do not indicate the actual movement of the mandible, but they do represent projections of the movements. Therefore, the *magnitude* of movement is exaggerated, and the *direction* of the movement is not necessarily the actual direction of movement. However, neither this nor the small amount of *real* movement invalidates the results.

Ralph W. Phillips reports on a comparison of the physical properties and accuracy of various elastic impression materials. He discusses their limitations and techniques for their use. He points out the need for further research on elastic impression materials and for an adequate laboratory test method to correlate with clinical observations.

Leon Krimer discusses the procedures he uses to increase the vertical dimension of occlusion for patients with natural teeth. The care he uses in diagnosis indicates that he recognizes the dangers involved in increasing this dimension beyond physiologic limits. The procedures for this type of service require a thorough understanding of occlusion as well as skill in the execution of the technique. The important occlusal coordination is accomplished in the mouth by causing the patient to "carve" the basic forms of the teeth after the vertical dimension and centric relation have been established.

Marvin K. Rubin discusses the procedures used in making full coverage restorations. He

compares various methods and describes his technique for making temporary crowns. If the procedure is properly carried out, it could save considerable time, and the temporary crowns can be valuable for maintaining the occlusion.

K. Asgar, W. N. Lawrence, and F. A. Peyton report on their investigations into the nature of hygroscopic expansion of dental casting investments. Their findings are important because they are directly related to variations in techniques and materials. They found two stages of expansion and that some of the phenomena which have been credited with causing the expansion failed to do so.

John O. Neufeld reports his studies of the changes in the trabecular pattern of the mandible following the loss of teeth. The external changes have been recognized by prosthodontists, and now these external changes are shown to be reflected into the interior of the mandible. An application of this information *could* lead to a more accurate prediction of the resorptive changes that occur under dentures. The techniques used in this study can serve as a basis for further study of changes in the bone. More investigation along the lines of this study is indicated. When this is accomplished, the answer to the prevention of ridge resorption may become apparent.

Douglas Allen Atwood reports on his clinical research regarding the variability of mandibular rest position. In this study, he correlates six groups of factors which influence the rest position of 42 patients. His contention of variation was borne out by the data, but the variation was not consistent from patient to patient, even when the same factors were involved. His findings seem to indicate that the use of the physiologic rest position as a means for determining the vertical dimension of occlusion may not be as precise as would be desirable. However, these facts should not rule out the use of physiologic rest position as *one* of several methods which should be checked against each other.

Joseph S. Landa reports his investigations of the so-called "Bennett movement." These investigations were designed to determine whether or not a directly lateral movement of the mandible does occur. He used many different approaches to the problem, including: studies of museum skulls, medical skulls, cadavers, roentgenography, cinefluorography, electromyography, and, finally, a duplication of Bennett's optical method. On the basis of his observations, he questions the validity of the Bennett movement. The methods he used show considerable ingenuity and an investigative thoroughness. It is significant that in *some* of the experiments a small number of subjects was used, and this *could* provide insufficient data for sound conclusions. On the other hand, his results seem to be consistent regardless of the methods used. Other methods and his conclusions will be reported in Part II of this article.

—Carl O. Boucher

COMPLETE DENTURES

THE DYNESTHETIC INTERPRETATION OF THE DENTOGENIC CONCEPT

JOHN P. FRUSH, D.D.S., AND ROLAND D. FISHER, D.D.S.
San Marino and Glendale, Calif.

THE DEVELOPMENT AND USE of an adequate functional procedure in prosthetic dentistry is the first step toward creating psychologic as well as physiologic comfort* for our patients. When this has been accomplished, we are ready for the final refinement of our prosthodontic service. This is the esthetic or dentogenic phase. The dentogenic theory of esthetics is a basic esthetic concept for all phases of dentistry where appearance is a factor. However, its success is reliant on good function. In fact, function and esthetics are inseparable and interdependent factors of prosthodontic procedure and success.

PREDIAGNOSTIC CONSIDERATIONS

The dentogenic concept of denture esthetics has been explained as the prosthodontic appearance interpretation of three vital factors which every patient possesses; sex, personality, and age. These factors have always been present as a challenge to the dentist in every phase of his dental procedures. No part of dentistry can be approached with anticipation of maximum success without a prediagnostic consideration of the sex, personality, and age of the patient. It is with a conscious consideration of these patient "constants" that the dentist has learned to apply his knowledge with the most effectiveness. The depth of understanding and the studious appreciation of these vital factors have helped to endow dentistry with the public respect due a mature profession.

To construct a dentogenic restoration effectively is a matter of learning and of interpreting the sex, personality, and age of the patient properly in the denture. This is done through detailed consideration of the three equally important parts of the denture: the tooth, its position, and the matrix. The qualities of femininity, masculinity, personality, and the various physiologic ages will be revealed in the

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This is the fifth of a series of six articles on Dentogenics in the JOURNAL (5:586-595 [Sept.] 1955; 6:160-172 [March] 1956; 6:441-449 [July] 1956; 7:5-13 [Jan.] 1957).
Received for publication July 3, 1957; revised by the authors Jan. 30, 1958.
*Pletcher, Delmer: Personal communication.

smile as a result of the way we do our interpretation. If the dentist and the technician properly treat the tooth, its position, and its matrix correctly, the pleasing personality is revealed, masculinity and femininity are effectively created, and the age of the patient is dignified in the smile. It has been shown that the application of dynesthetic techniques to the dentogenic concept has accomplished this and, thus, we have moved closer to our goal of bringing psychologic and physiologic comfort to all of our patients.

CLINICAL DEVELOPMENT

Psychologic comfort should be our goal in prosthodontics as well as physiologic comfort. This is the practical basis for final judgment of the success of dentures. It is impossible to anticipate the maximum success in denture construction for *all* patients but, esthetically, we have narrowed the gap between "trial and error" methods and have "predetermined success" by the development of dynesthetic techniques. However, the esthetic as well as the functional test of a denture is conclusive only in the mouth.

The years since 1950 represent an esthetic renaissance in dentistry. Many of today's writers are stimulating a re-examination of current esthetic procedures in the light of serious evaluation of the appearance of dentures in the mouth. It is a complex and challenging problem to give an edentulous patient teeth which compare favorably with natural teeth in authentic appearance. It is even more challenging and exciting to amplify this accomplishment by *enhancing* the appearance of each patient treated.

DYNESTHETIC THEORY

To apply the dynesthetic techniques in prosthodontics requires a knowledge of the dentogenic concept. The selection of artificial teeth, their subsequent sculpturing, the individual and detailed positions of these teeth, and the color and contours of the denture base are all part of the dynesthetic techniques and cannot be done in a comprehensive manner without reference to the patient's sex, personality, and age as primary factors. For example, artificial teeth are selected according to the personality of the patient,[2] subsequent sculpturing is directed toward accentuating masculinity or femininity,[1] and the denture base color and contour helps satisfy the age factor.[3] We call the secondary factors of a dentogenic restoration dynesthetics.

Dynesthetics is a compounded word. The prefix *dyn* is the combining form from the Greek word *dynamis,* meaning power. The literary license used in combining the prefix *dyn* with the word *esthetics* is necessary to the description of the philosophy and techniques of these supporting or working factors of the dentogenic concept. We wish to imply movement, action, change, and progression in the esthetic phase of prosthodontics. By the inclusion of the dynesthetic philosophy, we experience an orientation in appearance identification. For instance, the word *esthetic* applied by itself to dentistry becomes an overabstraction and, therefore, is applicable to almost anything according to anyone's interpretation. The word *esthetic* does not suffice because it does not identify the intent of the effort.

PRINCIPLES OF ART

In the word dynesthetic, we use the meaning of dynamic as applied to the fine arts. In this application[4] it means producing the effect of movement or progression. This dynamic value has been described as marking the difference between an artifact (any object without "life effect" made by man, such as a spoon) and a work of art (visual objects that are alive in meaning, such as a statue).*

These considerations are found to be useful in prosthodontics because their value has been established as a rudimentary principle of art. Dentists have the responsibility of sculptors in a highly sensitive area of expression. Therefore, because of this recognized artistic responsibility, our work is subject to examination in the light of these principles of art.

Most emotional social intercourse of a patient is effected by his facial expressions. The dentist's degree of skill in the treatment of the patient's edentulous condition is, therefore, extremely important. In our own prosthodontic treatment, the denture, as a work of art, is far more to be desired because of its "life effect" than a denture lacking artistic treatment, such as an artifact.

THE CHANGING PROSTHODONTIC PROBLEM

The physical environment of an edentulous mouth is in constant and permanent change. For this reason, our creative effort in treating edentulous patients should follow this change and progression. Our dentures can follow the changing physical personality traits of the patient as well as physiologic age changes in the tissues. Dynesthetics affords a comprehensive method of doing this by a progressive adaptation of these working principles to the constantly changing environment of the original restoration. Thus, dynesthetics has a succinct and pointed meaning for our procedure, and the word supplies a nucleus from which these techniques develop. The patient can be made aware that maintaining a harmonious status between their dentures and a constantly aging and changing physical appearance requires progressive analysis and treatment. New dentures which follow the changing physical personality are the factual solution. The time cycle for new dentures depends upon the patient's individual requirements and may vary from two years up. Intraoral as well as extraoral changes affect the appearance of the dentogenic composition.

The technique of dynesthetics, however, must be considered as merely an auxiliary stimulus in the creation of a dentogenic restoration. It is secondary to the sex, personality, and age factors and, therefore, in itself, is not creative art.

AREAS OF RESPONSIBILITY

The dynesthetic techniques are rules which concern the three important divisions of denture fabrication: (1) the tooth, (2) its position, and (3) its matrix (visible denture base).

Dynesthetic techniques are not to be confused with dentogenic procedure. Dentogenic procedure is the application *by the dentist* of these rules in the sequence of esthetic planning and are applied according to the sex, personality, and age

*Bernard Berensen, art critic and art historian.

considerations. Therefore, it is important at this time to make the delineation between the dynesthetic accomplishments of the dental technician in his laboratory procedure and the final dentogenic restoration as can only be created by a dentist.

The laboratory technician cannot produce a dentogenic restoration, because he does not come in direct contact with the patient; nor is he professionally trained to meet the challenge posed by the complexities of patient management. His laboratory accomplishment is based upon the information given him by the dentist (Fig. 1). This information varies according to the desires of the individual dentist in his procedure. The laboratory result is a matter of training and the

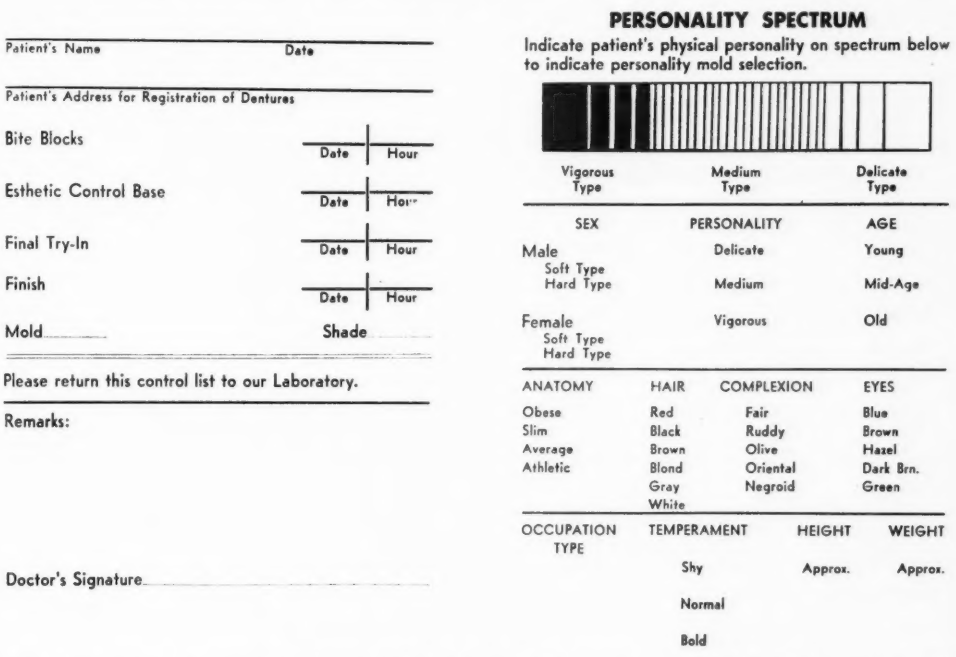

Fig. 1.—A special prescription form has been created to convey pertinent sex, personality, and age information to laboratories trained in the dynesthetic techniques.

desire of the technician to maintain his own work at the proper level. For instance, the following operations can be accomplished by a laboratory technician as supplementary help to the dentist's efforts: depth grinding, abrasion, and identification of masculinity or femininity; smiling line; specific positioning and rotation of central incisors, lateral incisors, and cuspids; positioning and spacing of posterior teeth; embrasures and diastemas; buccal corridor; long axes of the teeth; papillae; gum line, self-cleansing denture base contouring and tissue stippling; packing by the dry technique; pressing and postpolymerization in the flask; age factor; buccolingual grinding of posterior teeth; self-cleansing design of diastemas and interdental papillae and the lingual cutaway.

Special prescription forms have been developed to convey more information to the technician (Fig. 1). These prescriptions exact a high degree of excellence from him and place added responsibility on the dentist, where it should be.

The efforts of the technician and dentist can be correlated only by that intimate knowledge of the patient which is available to the dentist. The prescription containing pertinent information about the physical personality of the patient gives the technician an opportunity to improve his service (Fig. 1). With the prescription, he is able to provide the technical ability and understanding which relieves the dentist of many tedious and time-consuming laboratory operations. The skilled technician's ability, then, allows the dentist maximum opportunity to further refine the dynesthetic rules according to his own perception of the sex, personality, and age requirements of the patient at the try-in appointment. Thus, the dentist completes the creative effort of both his own and the technician's effort and brings it to the status of a dentogenic restoration.

DYNESTHETIC OUTLINE

A dentogenic restoration is fabricated within the framework of dynesthetic procedure. Any compromise or short cuts will make the finished restoration more like an ordinary denture.

The object of our work is to benefit the public through the medium of better professional understanding of the needs of the patient's psychologic comfort and to achieve this object through a comprehensive and practical approach to a complete esthetic treatment.

NEW MATERIALS

Many new materials were needed and are available for this work. Some of them have been developed to meet the requirements of dynesthetic procedure. Many materials and devices developed for the dental profession are for the convenience of the dentist. With very few exceptions, it is dental skill and understanding which produce good dental service. The ease with which this is done depends, to a great extent, upon the use of adequate instruments and materials. If we recommend the use of certain materials, it is only because we believe they more adequately suit the needs of dentogenic restorations and the dynesthetic procedures and make the final accomplishment more consistent.

PHYSIOLOGIC SHADE SELECTION

Artificial tooth shades should be classified according to the physiologic color changes seen in progressively aging, undiseased natural teeth. For instance, when a permanent central incisor erupts, the mamelon is intact on the incisal edge and the fresh, unmarred qualities of the teeth are essentially sealed in by an unbroken enamel cap. Young teeth, therefore, have a blue incisal edge due to the light refraction through the two layers of enamel. The body of a young tooth is usually a solid and opaque color with very little or no color texture. Our purpose is to create the illusion of natural dentition, e.g., for a young person, we would select artificial teeth with a blue incisal edge and a yellowish unmarred body.

At about 30 years of age, the incisal mamelon is worn through, and the dentinoenamel junction is exposed to the fluids of the mouth. Tobacco tar, food pigments,

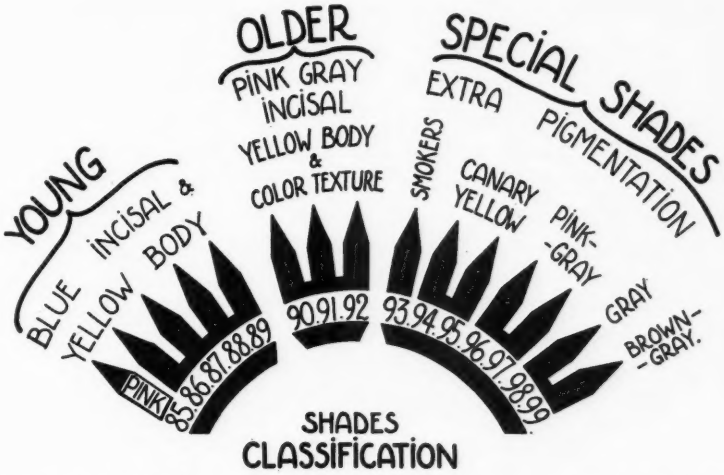

Fig. 2.—A physiologic shade selection chart (Swissedent Foundation). Natural teeth do not necessarily darken with age. Color texture always appears with age but it may not darken the tooth. Older teeth with color texture are sometimes lighter than young unmarred teeth. For instance, the point on the color chart designated as 90 should be lighter than the point on the younger color chart designated as 89.

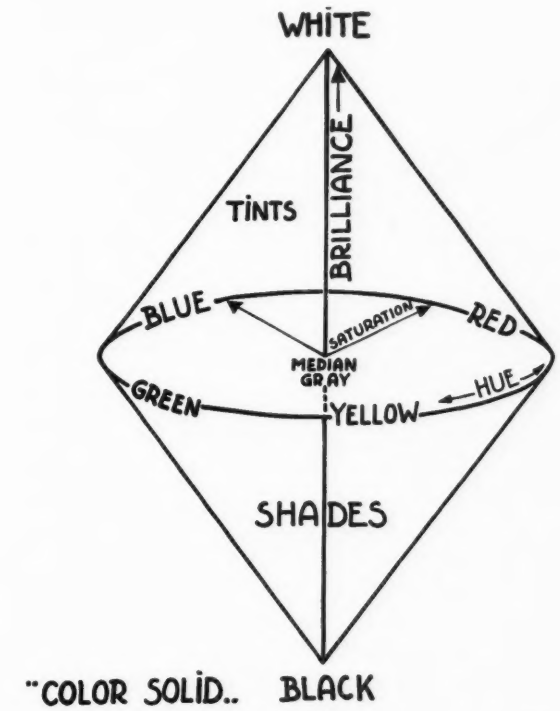

Fig. 3.—A chart of color solid. Brilliance is a measure of gray. Color texture in natural teeth is developed by the reflection of minute degrees of hue, saturation, tints, and shades produced by a myriad of enamel defects and pigment penetration. *(After* Webster's New International Dictionary, ed. 2, Springfield, Mass., 1944, G. & C. Merriam Co., p. 528)

and bacterial discoloration soon change the fresh, unmarred qualities of the natural teeth. As this occurs, various degrees of color texture are noticed at the incisal edge and upward in natural teeth, and they occur in direct proportion to the age of the patient. Therefore, in creating the illusion of natural dentition for an older person, we would select a shade of artificial tooth which represents this aging process, but this does not necessarily mean darker teeth for older people.

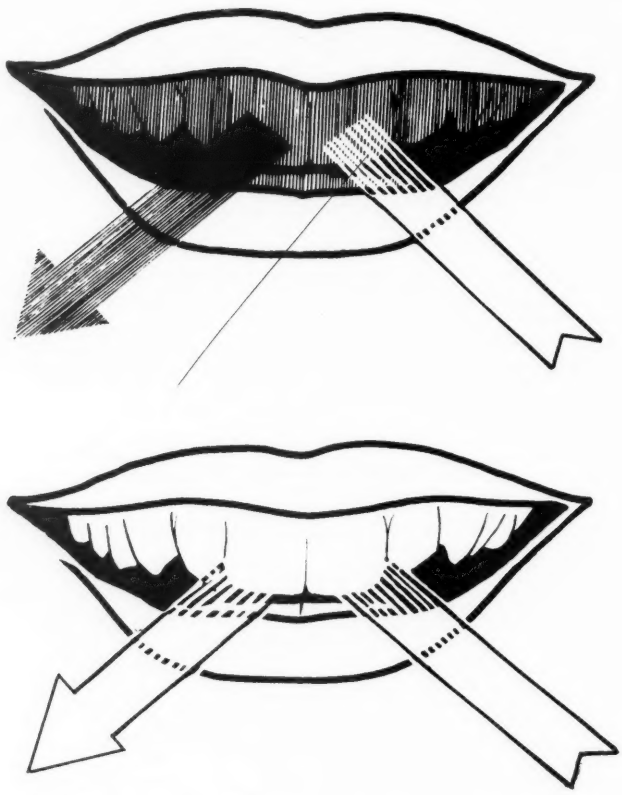

Fig. 4.—The interior of the mouth behind the teeth is dark, and this darkness will be picked up by the teeth, either natural or artificial, as a dead gray unless the tooth structure itself curtains this black area by its own light reflective qualities. Otherwise, various degrees of brilliance instead of normal tooth radiance will result. *Above*, Light absorption is not natural; *below*, light reflection is natural.

A person who does not smoke and who takes foods of slight pigmentation may continue to have a relatively light tooth body, together with the normal color texture. For this reason, we must have some artificial teeth for older people in which are incorporated the quality of color texture and, at the same time, a whiter body color. We must have shades available for older people which are lighter than *some* of those for younger people (Fig. 2). This is physiologic shade selection.

One other necessary quality of shades of artificial teeth is that of the unusual or special shades seen in natural teeth. These are a separate classification from that of young and older teeth. These special shades occur naturally as smoker's

shades, canary yellow shades, pink-gray, gray, and gray-brown. Special shades are used mostly in fixed and removable partial dentures and porcelain jacket crowns to match natural tooth colors.

The dentist's understanding of these color requirements in artificial teeth should properly lead to independent considerations and choice. The color chart from Webster's dictionary[4] is easily analyzed and understood (Fig. 3). The axis of the double cone (AB) is called *brilliance*, and brilliance is a measure of gray from white to black. It is not, therefore, a desirable quality in artificial teeth. A study of natural teeth will show this and demonstrate instead the color principles of hue and saturation which make up the important quality of color texture produced by *color transmitting light reflection* (Fig. 4).

In recent years, tooth porcelain, both for jackets and denture teeth, has been strengthened by vacuum firing. Unfortunately, vacuum firing in itself produces a greater incidence of light and color absorption and causes a condition known as "graying out," as shown in Fig. 4. Light absorption and brilliance go together to produce varying degrees of grayness, as shown in the color chart.

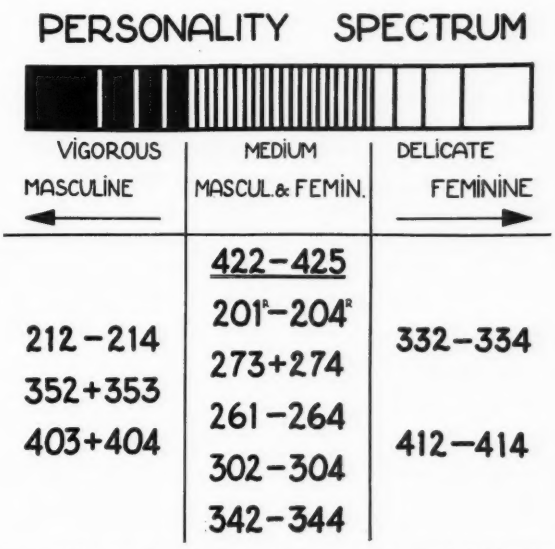

Fig. 5.—The personality spectrum[2] as a measure of physical (objective) personality remains as the best guide to mold selection. This chart shows an effective adaptation of selected molds to the personality spectrum for excellent results in our experience. Each dentist should arrive at his own choice of these molds through trial and follow an independent course of creative effort.

Advanced vacuum firing methods and new porcelain formulae are inconvenient for the manufacturer and are more expensive, but the light reflection quality of the dentition is maintained. Therefore, color texture and light reflection go together; this is the normal quality of natural teeth.

CONSIDERATIONS IN DYNESTHETICS

The following are dynesthetic considerations which are necessary to the production of a dentogenic restoration.

Fig. 6.

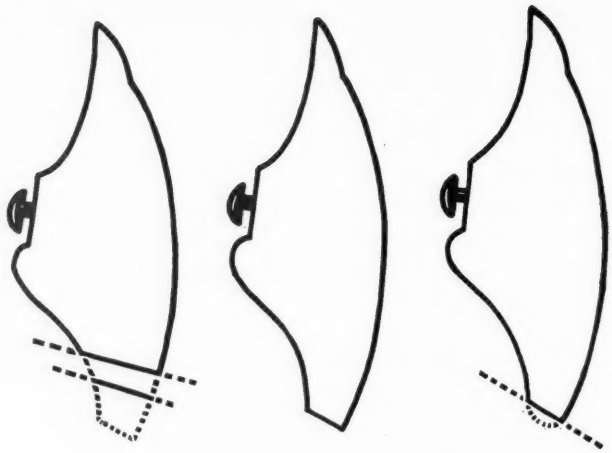

Fig. 7.

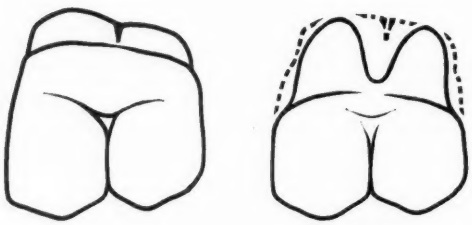

Fig. 8.

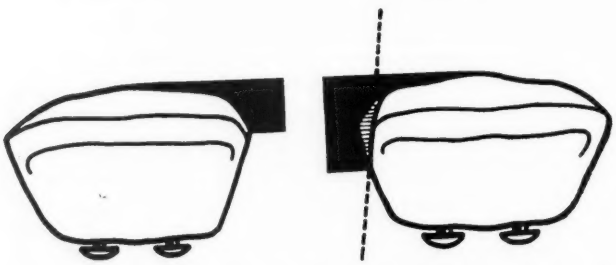

Fig. 6.—*Left,* The progressive abrasion of the artificial tooth as the age of the patient progresses. *Middle,* The cut made for normal abrasion to remove the artificial appearance of the incisal edge.[4]

Fig. 7.—*Left,* A posterior diatoric tooth to be modified to simulate erosion. *Right,* The subsequent grinding and polishing presents an illusion of natural erosion which can be achieved similarly with anterior teeth in lesser degrees.

Fig. 8.—*Left,* Depth perception is limited in the artificial tooth because the contact point is too near the labial surface. *Right,* The depth of perception has been increased by depth grinding. This is a cut made on the labial mesial line angle of the artificial tooth.

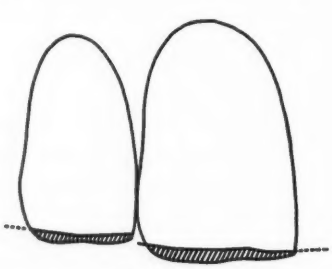

Fig. 9.

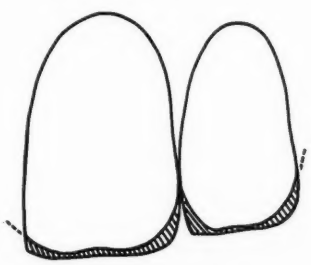

Fig. 10.

Fig. 9.—In personality mold selection (Fig. 5), a delicate mold is feminine, and a vigorous mold is masculine. A medium pleasing personality mold is made more masculine by squaring the incisal edges.

Fig. 10.—A medium personality mold is modified to appear more feminine.

MOLD

The selection of an acceptable personality mold (Fig. 5) involves its subsequent treatment for abrasion (Fig. 6), erosion (Fig. 7), depth grinding (Fig. 8), masculinity (Fig. 9), or femininity (Fig. 10) shaping and polishing.

LIP SUPPORT

This is the bodily anteroposterior position of the teeth (Fig. 11) which adequately supports the upper lip in a natural and pleasing manner. The placement of the upper anterior teeth for proper lip support is an independent procedure. It is not controlled by any other consideration of cranial relation or opposing tooth position. It may be modified to accommodate, but it is not controlled. It is subject to slight modifications and adjustments as the work proceeds, but pleasing lip support is sacrificed only in the most extreme instances of old age or other circumstances where esthetics is of little consideration in the psychologic and physiologic comfort of the patient.

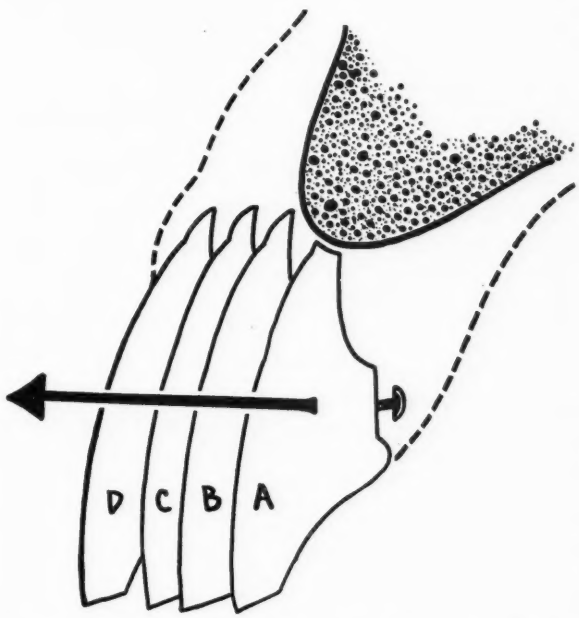

Fig. 11.—Pleasing lip support is achieved by the anterior teeth and their matrix. The burden of lip support is carried chiefly by the central incisors. Position *A* is for maximum mechanical stability. Positions *B*, *C*, and *D* represent the progressive dynesthetic positioning of the central incisors for pleasing lip support.

MIDLINE

The features of a face usually slant one way or another and it is rather difficult to see a true midline in a dentition. It is usually more eccentric than is noticed. Therefore, an eccentric midline in a denture, if not too exaggerated, is ac-

ceptable and may lend to the illusion of the natural dentition. The mid-axis (Fig. 12) is important to general composition and should be vertical to the incisal and occlusal plane.

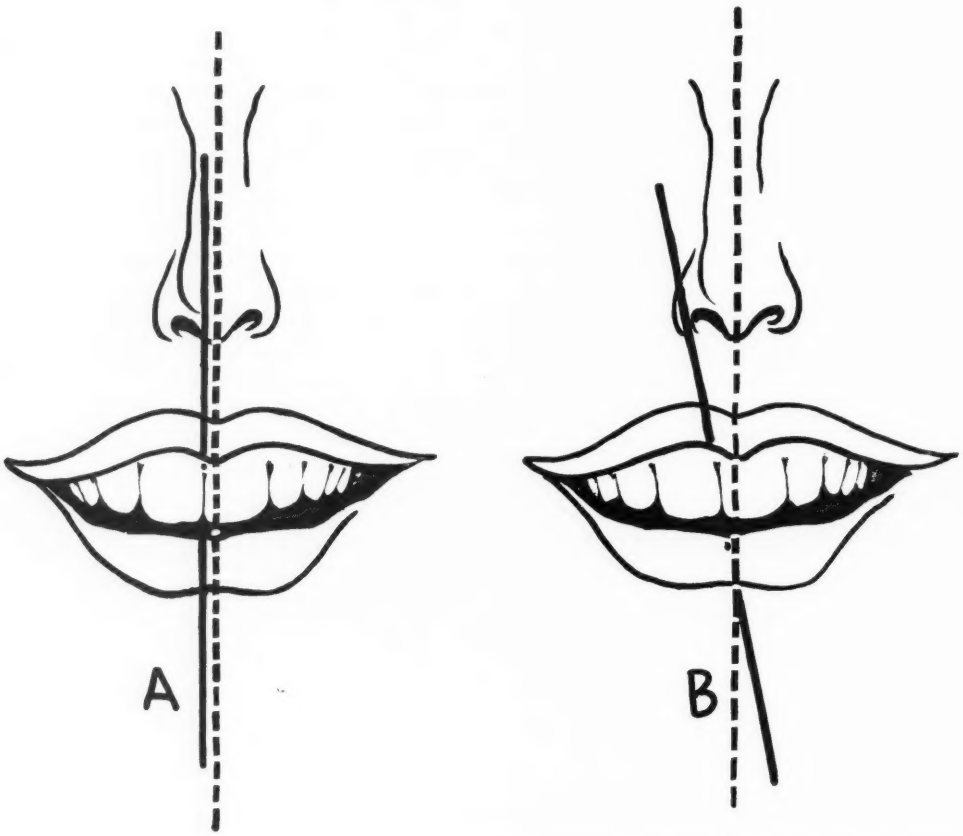

Fig. 12.—*A*, An acceptable midline (solid line). *B*, An error in composition which results when the mid-axis of the central incisors (solid line) is not vertical.

LABIOVERSION

Labioversion is necessary because the most pleasing effect is obtained when the long axes of the central incisors are either vertical or with a slight labial inclination. This determination is made by observing the teeth in profile when the patient is standing in normal posture.

SPEAKING LINE

The speaking line is the incisal length or the vertical composition of the anterior teeth (Fig. 13). It is spoken of as the speaking line because the final evaluation of the incisal length is made when the patient is speaking. When the patient

is speaking seriously, we should see the tip of the lateral incisor. A guide to vertical composition using the incisal edges of the central incisors in their relationship to the lip line, at rest, as a measure is as follows:

(a) Young woman	3 mm. below lip line at rest
(b) Young man	2 mm. below lip line at rest
(c) Middle age	1½ mm. below lip line at rest
(d) Old age, senility	0 mm. below lip line at rest to 2 mm. above lip line at rest

It follows, therefore, that according to this guide the tips of the lateral incisors should show in varying degrees according to the sex and age requirements.

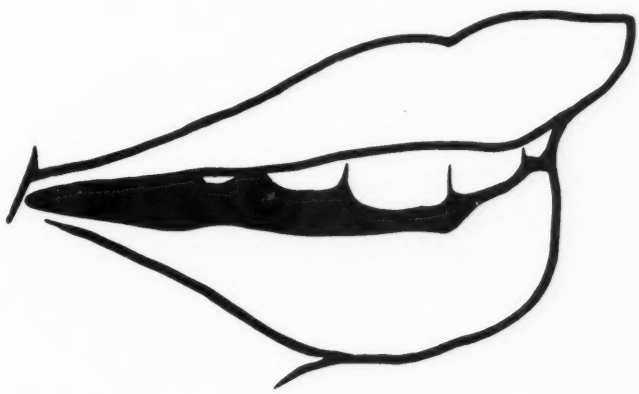

Fig. 13.—The speaking line is correct because a portion of the lateral incisors show when the patient speaks seriously.

SMILING LINE

The smiling line is a curve whose path follows the incisal edges of the central incisors up and back to the incisal edges of the lateral incisors and, thence, to the tips of the cuspids (Fig. 14,*A*). Its arc is determined by the age of the patient and decreases as the patient gets older (Fig. 14,*B*). The smiling line is a secondary vertical composition of the individual six anterior teeth and is subject to the interincisal distance (Fig. 15).

CENTRAL INCISOR POSITION[2]

The central incisors are the cornerstones of tooth position. If their positions are correct, then the positions of all of the other teeth will be more nearly correct, and their placement controls (a) the midline, (b) the speaking line, (c) the lip support, (d) labioversion, and (e) the smiling line composition.

The central incisors are also the basis of personality mold selection. Their importance lies in their primary forward position in the mouth; they are the first teeth to be seen in the smile. Their shape is controlled by the physical personality

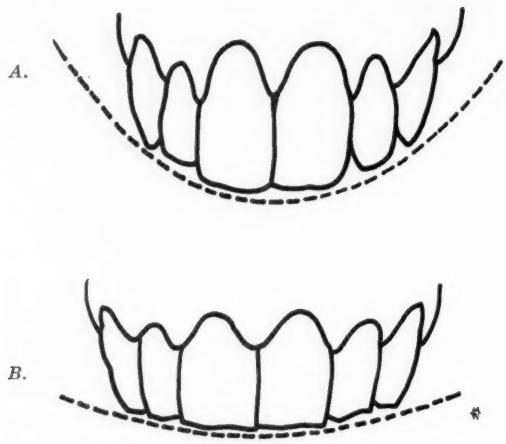

Fig. 14.—*A*, The sharp curve of this smiling line is youthful. *B*, The broader curve of this smiling line indicates an older dental composition.

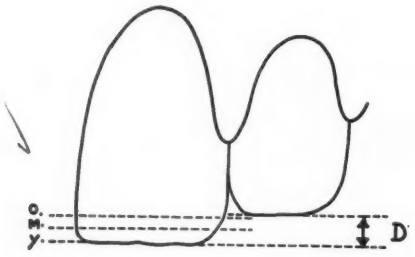

Fig. 15.

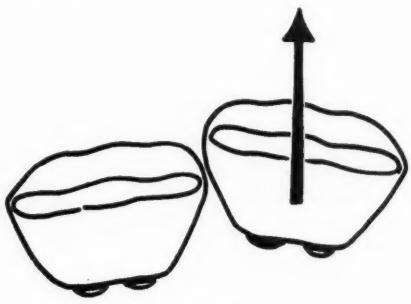

Fig. 16.

Fig. 15.—*D*, Interincisal distance. The incisal edge at *o* indicates a slight interincisal distance represented by an older dental composition. The incisal edge at *m* indicates a middle age interincisal distance. The incisal edge *y* indicates a youthful interincisal distance.

Fig. 16.—One central incisor is nearly always placed bodily ahead or behind the other central incisor.

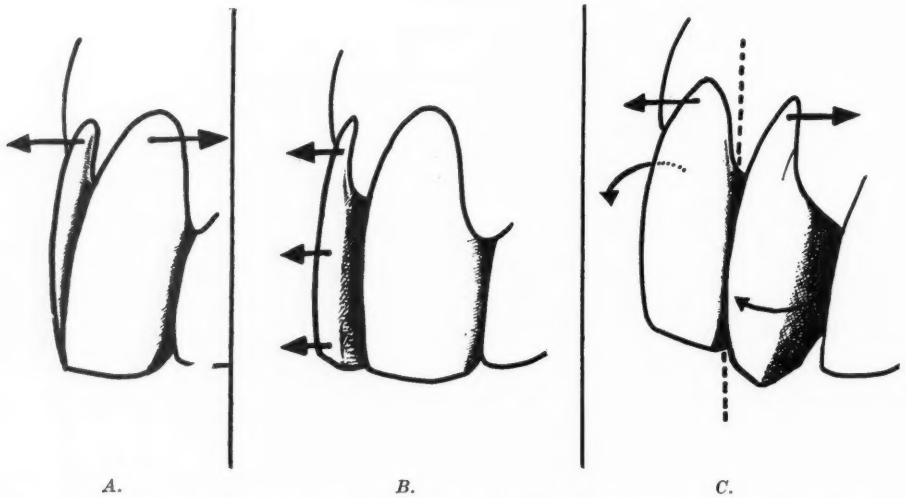

Fig. 17.—*A*, The dynesthetic position of one cervical end in and one cervical end out. *B*, The bodily forward position of one central incisor. *C*, The extremely active and strong position of a combination of positions as follows: one cervical end is in, and one is out, one tooth is placed bodily ahead of the other, and the distal surfaces have been rotated forward on their axes.

Fig. 18.

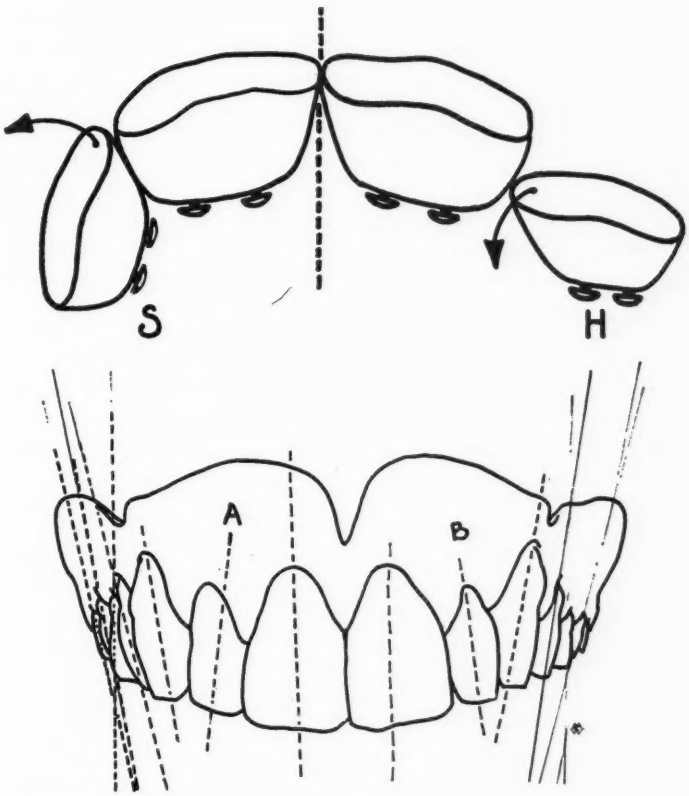

Fig. 19.

Fig. 18.—The *soft* position of the lateral incisor *(S)* is produced by rotating its mesial surface outward. The rotation of the mesial surface inward *(H)* produces the *hard* position of the lateral incisor.

Fig. 19.—The long axes of the lateral incisors *A* and *B* must be asymmetrical.

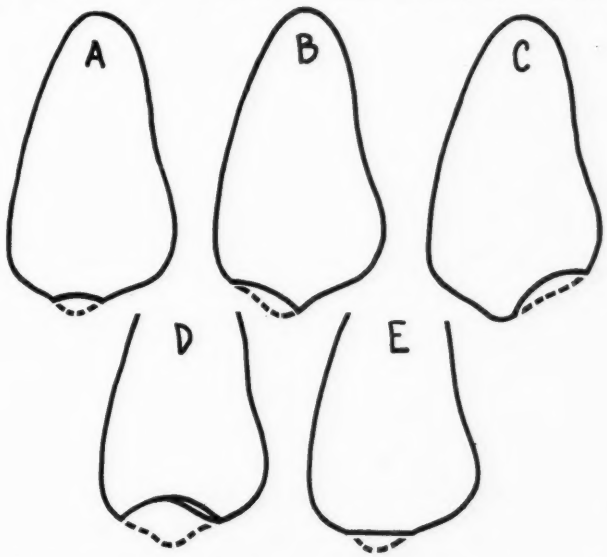

Fig. 20.—Cuspids should be abraded according to the age of the patient, and this abrasion should be made in a curve as in *A*, *B*, *C*, and *D*. *E* illustrates an unnatural and improper flat abrasion.

of the patient, and their position determines the strength and action of the dentogenic composition.

The relationship of the central incisors to each other is important. One central incisor is always placed bodily ahead or behind the other (Fig. 16). From this point on, various degrees of rotation, labial inclination, and axial divergence will produce effects of additional strength, activity, and vigor to the entire dental composition (Fig. 17).

The central incisors should contrast sharply in size with the lateral incisors. The degree of contrast is subject to the experience and interpretation of the dentist. This can be accomplished easily by selecting a smaller sized lateral incisor and cuspid in the same mold as the central incisor.

The central incisors must be depth ground (Fig. 8). The central incisors must dominate the lateral incisors in their positions within the general curve of the anterior dental arch. The lateral incisors should always fall within the line of the arch, assuming the central incisors form the anterior limit of the arch form.

LATERAL INCISOR POSITION[2]

The position of the lateral incisor is subordinated in importance to that of the central incisor. Its rotation, however, will either harden or soften (Fig. 18) the dental composition.

The right and left lateral incisors should have asymmetric long axes (Fig. 19). The lateral incisors should be positioned so that at least a portion is seen when the patient speaks seriously (speaking line determination).

In dentogenics, the lateral incisor is considered to be the personality tooth. The sex determination comes from either rounding the incisal edge for feminine effect or from squaring the incisal edge for masculine effect (Figs. 9 and 10). The patient's personality is interpreted by the sculptured form of the tooth and the soft and hard positions described above.

THE CUSPID POSITION[1]

The position of the cuspid tooth in the general arch form is important because it supports the anterior arch form in its widest part and controls the size of the buccal corridor. The cuspid should be carefully positioned so as to dominate the lateral incisor and to complete the desired upward curve of the smiling line. The cuspid should be abraded to convey the physiologic age of the patient in the dental composition (Fig. 20).[3] The three basic requirements of the cuspid tooth position are: (a) the tooth should be rotated to show its mesial surface (Fig. 21,*A*), (b) the cervical end (not the tip) should be out (Fig. 21,*B*), and (c) observed from the side, the long axis of the cuspid should be vertical (Fig. 21,*C*).

SPACES

Spaces between the anterior or posterior teeth are extremely effective, but their size and position must be artistically and hygienically formed, or they will become unsightly repositories for food, bacterial plaques, and calculus. We usually

speak of *diastemas* between the anterior teeth and spaces between the posterior teeth. Both terms are synonymous and mean a separation of the proximal surfaces of the teeth. The rules which must be observed with spaces follow. (a) All spaces must be V-shaped to shed food (Fig. 22). (b) A diastema between the

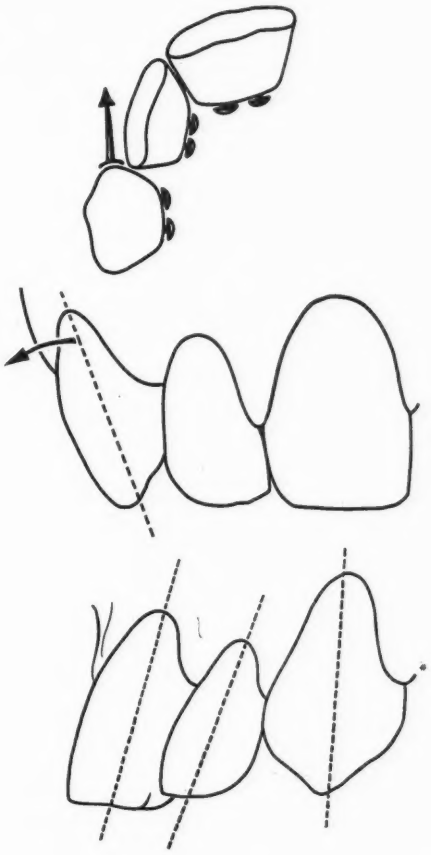

Fig. 21.—The position of the cuspid tooth. *A*, The proper rotation of the cuspid tooth exposes its mesial surface. *B*, The cervical end of the cuspid is moved out. *C*, The long axis of the cuspid is vertical when viewed from the side of the face.

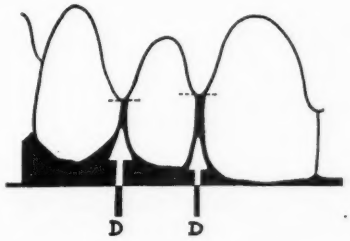

Fig. 22.—The V-shaped areas *D* are the proper self-cleansing form of all diastemas.

central incisors is unsightly and should be avoided. (c) Diastemas should be asymmetrically placed on either side of the dental arch. For instance, if a diastema occurs between the lateral and central incisor on the right side of the arch, it should not be repeated between the lateral and central incisor on the left side of the arch. (d) The width of the diastema should be controlled so as not to appear unsightly at any instance. Diastemas which are too wide appear as black holes. Conversely, diastemas which are too narrow are difficult to construct so as to shed food. Therefore, if an extremely narrow diastema is desired, an embrasure should be used instead.

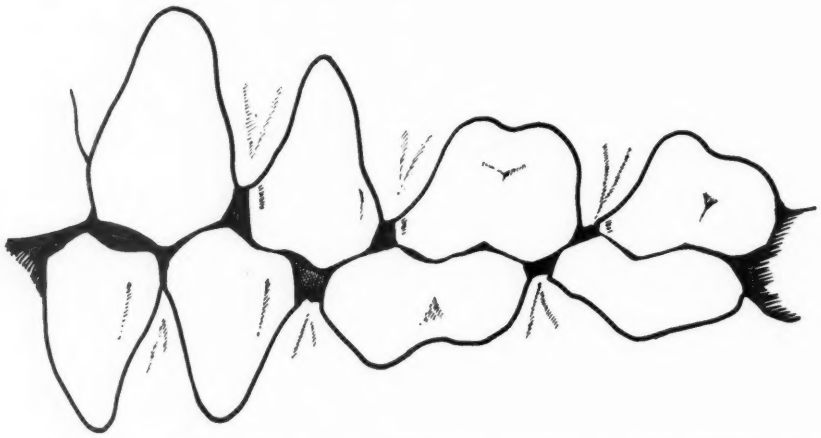

Fig. 23.—One tooth is eliminated from a posterior quadrant to obtain freedom of position for the others in the posterior dental composition. This allows V-shaped diastemas for spillways and additional cutting edges achieved by sharpening the marginal ridges by interproximal grinding.

Spaces are always placed between the posterior teeth. This allows additional spillways for food through these spaces and creates additional cutting edges from the marginal ridges. These cutting edges are sharpened by grinding the proximal surfaces of the posterior teeth (Fig. 23).

EMBRASURES

An embrasure gives freedom to the dental composition and differs from the diastema or spaces in that it represents a divergence of the proximal surface of the anterior teeth from the contact point (Fig. 24). There is no separation of the proximal surface since the contact areas are touching. An embrasure is employed in the same manner as the diastema or spaces but much more frequently.

BUCCAL CORRIDOR

The buccal corridor is a space created between the buccal surface of the posterior teeth and the corner of the lips when the patient smiles (Fig. 25). The

buccal corridor begins at the cuspid, and its size and shape are controlled by the position and slant of the cuspid even though the actual corridor exists posterior to the cuspid tooth. The size of the buccal corridor is not critical and can be judged adequately by the eye in comparison with the natural dentition. The use of the buccal corridor prevents the "sixty tooth smile" or the "molar to molar smile" which is often characteristic of a denture.

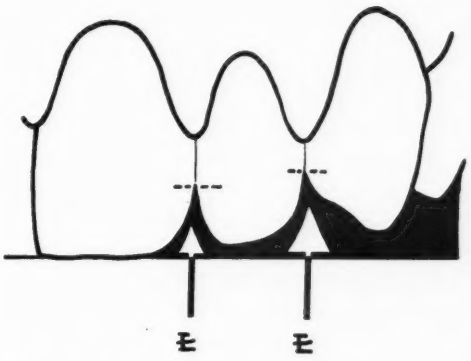

Fig. 24.—The arrows *E* point to the embrasures which add a senes of freedom to the appearance of the dental composition.

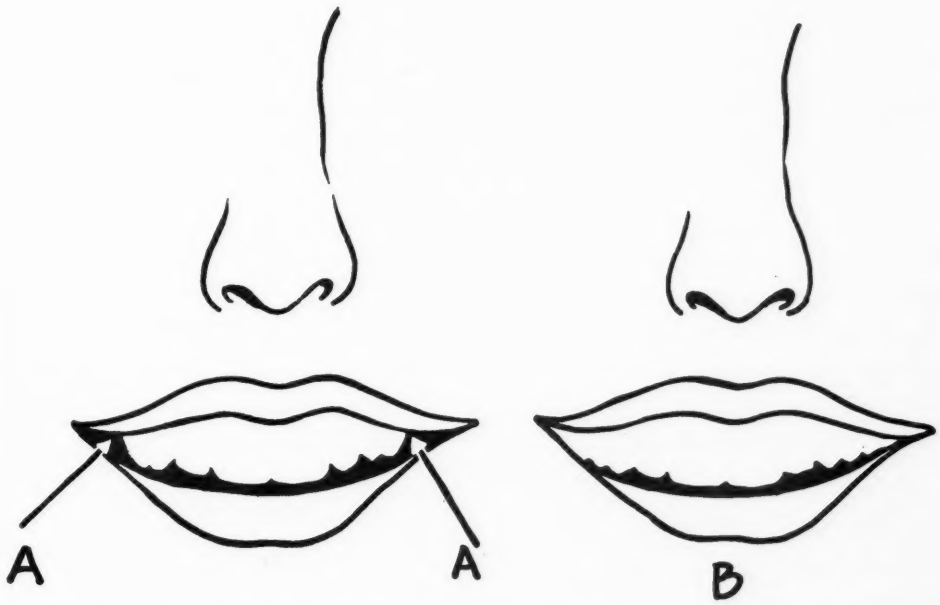

Fig. 25.—The buccal corridor *A* is present in the natural dental composition. Its inclusion in dentogenics accomplishes an added illusion of reality. *B*, Note the "molar to molar smile" which is characteristic of a denture.

LONG AXES

Upon close examination of the position of natural teeth, it will be noticed that their long axes vary. Even though this variance is sometimes in minute degrees, it is there and should be exaggerated in the dentogenic restoration as an artistic device (Fig. 19).

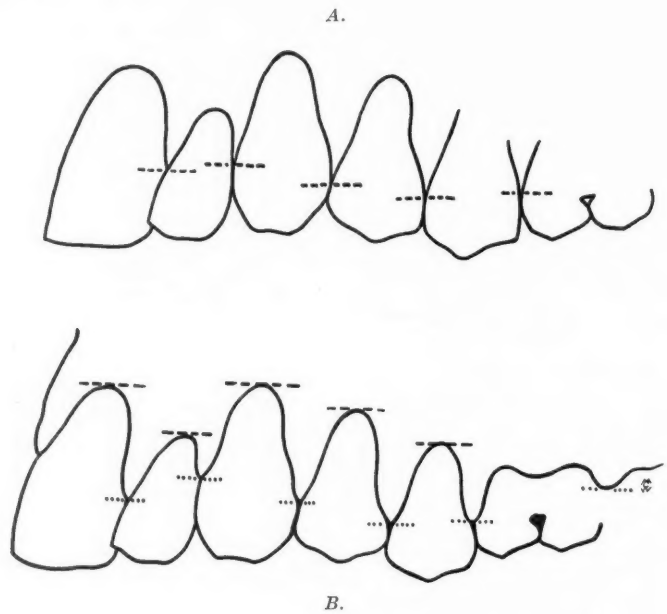

Fig. 26.—*A*, The variation of the levels of contact points. *B*, A general guide for establishing the height of the gum line of each tooth.

GUM LINE

The gum line at the cervical ends of the teeth should vary in height (Fig. 26). The generally acceptable rules for this are that the gum line should be formed (a) slightly below the high lip line at the central incisors, (b) lower than the central incisor gum line at the lateral incisors, (c) higher than the central or lateral incisor gum line at the cuspid, and (d) slightly lower than at the cuspid, at the bicuspid, and variable for the bicuspids and molars.

INTERDENTAL PAPILLA

The interdental papilla forms the main part of the tooth matrix (visible denture base). Therefore, it occupies one-third of the total importance of the dental composition. The other two-thirds are occupied by the tooth and tooth position.

It has been customary to remove the base material from between the teeth, so as to expose as much tooth as possible and to hide as much of the denture base

as possible. Fortunately, more attention is being given the natural form of the interdental papilla, and this study is being translated by various techniques into the entire denture base. A certain amount of confusion exists about the esthetic limits of the denture base, and this leads to the use of overcomplicated techniques. In a dentogenic restoration, the esthetic consideration of the denture base lies in the matrix of the tooth. This is the part of the denture base that is visible when the patient speaks or laughs. The balance of the denture base, as seen on the articulator or in the hand, is unimportant esthetically. Therefore, a dentogenic analysis is made with the denture in the mouth. We are concerned only with that which we see in this environment.

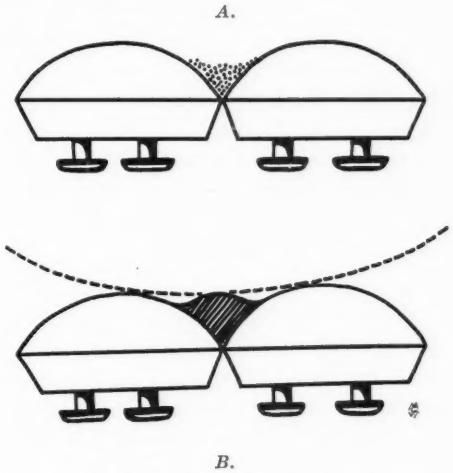

Fig. 27.—*A*, When the interdental papilla does not fill the interdental space by extending to the contact point, a food trap is created which traps soft foods while the patient is eating. Subsequently, these same areas become stained by calculus, food pigments, and bacterial placques. *B*, In this contour of the papilla, food is readily swept from the interdental area by the normal action of the tongue, lips, and cheeks.

Since we reproduce only that which is pleasing in nature, we do not copy diseased or unsightly natural gum contour. Also, since the requirement of a dentogenic restoration is that of a self-cleansing design, we do not reproduce any condition of the dentition which contributes to uncleanliness or eventual discoloration of any portion of the denture, especially the surfaces between the artificial teeth. It is for this reason that no space is ever allowed above the contact points in our dental composition. Holes above the contact points may appear natural the day a denture is inserted, but seldom do we find a patient who will keep these holes clean, polished, and free of stain or debris. The interdental papilla must come to the contact points in order to eliminate this unhygienic area (Fig. 27,*A*). This is the first rule of interdental papilla formation.

The correctly formed interdental papilla accomplishes four definite purposes. (1) It creates a hygienic, self-cleansing interdental area (Fig. 27,*B*). (2) It is a complimentary factor in age interpretation (Fig. 28). (3) It determines the outline form of a tooth and makes the two-dimensional outline form of a tooth incidental to other esthetic requirements, such as the age interpretation in the papillae

and the personality identification in the sculptured form of the tooth. The proper shape of the papilla can change a square tooth into a tapering tooth or an ovoid tooth. (4) It brings a degree of color reflection to the interdental area which creates the illusion of a natural dental composition.

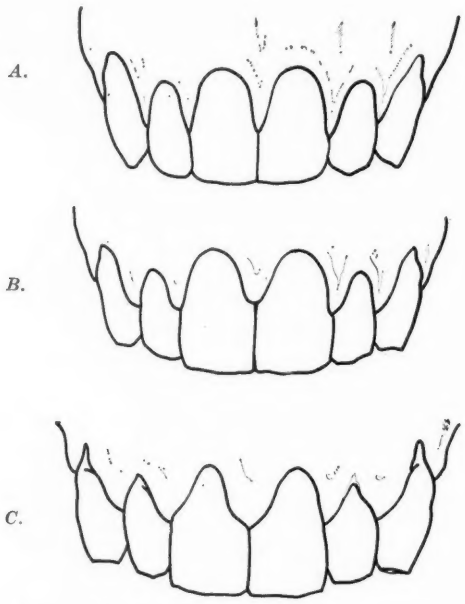

Fig. 28.—*A*, The normal youthful contour of interdental papillae. *B*, The shortening of the papillae is noticed as the age of the patient progresses. *C*, The papillae become progressively shorter and wider in the older dentogenic interpretation.

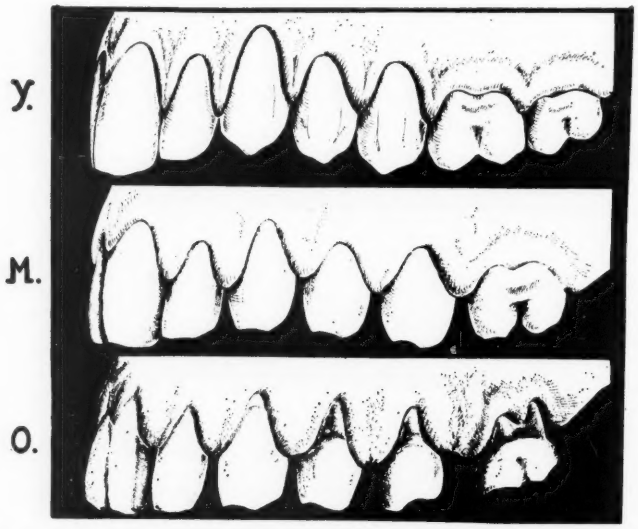

Fig. 29.—Interdental surfaces of the papillae must be convex in all directions to be self-cleansing. This convexity can be made in young papillae *(Y)*, in middle-age papillae *(M)*, and older papillae *(O)*, and thus it becomes a complementary factor in age interpretation.

The general rules for the formation of the interdental papilla are as follows: (a) the papilla must extend to the point of tooth contact for cleanliness (Fig. 29); (b) the papillae must be of various lengths (Fig. 28); (c) the interdental papilla must be convex in all directions (Fig. 29); (d) the papillae must be shaped according to the age of the patient and they are classified as young, middle-aged (average), or old-aged (Fig. 29); (e) the papilla must end near the labial face of the tooth and never slope inward to terminate toward the lingual portion of the proximal surface (Fig. 30).

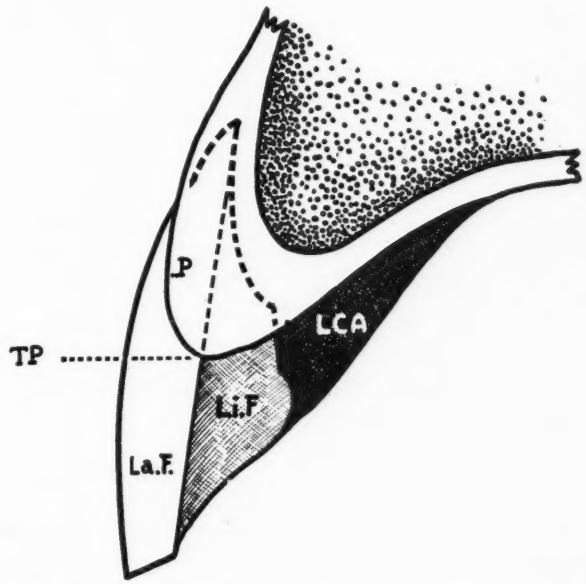

Fig. 30.—The interdental papilla *(P)* should extend to the contact point and be convex. The tip of the papilla *(TP)* should end, at its lowest point, at the juncture of the labial face *(La.F)* of the tooth and the lingual face *(Li.F)* of the tooth. As the papilla terminates, it then turns upward and back to form the bottom of the groove which is known as the lingual cutaway *(LCA)*.

LINGUAL CUTAWAY

The lingual cutaway is a groove in the lingual interdental surface which begins at the contact points of the teeth if they are together or at the tip of the interdental papilla if there is a diastema. It widens and deepens according to the natural divergence of the lingual proximal tooth surfaces. It fades away into the palatal surface of the denture.

The reason for the lingual cutaway is that food, when incised, will sweep through this polished channel and keep the area clean. It also prevents an unnatural exposure of plastic behind the tip of the papilla.

LABIAL AND BUCCAL DENTURE BASE CONTOUR

We think of a natural base contour as being convex, vertically, from the denture border to the tip of the interdental papilla in the anterior region. This neces-

sitates a rather modest thickness of the border of the labial flange from buccal frenum to buccal frenum and eliminates the distortion of the mucolabial fold which appears too often as a bulge underneath the nose. A thickened anterior border of the wax occlusion rim distends the lip unnaturally outward and upward and should be prevented because this would disturb the proper recording of the low lip line.

The denture base contour beyond the matrix (visible denture base) should provide a self-cleansing surface and, therefore, should not be overaccentuated with depressions, grooves, wrinkles, folds, or any shape which would defeat the smooth cleansing action of the cheek or lips. Characterization for esthetics of the denture base beyond the visible portion is an impractical waste of time and effort.

FINAL CRITIQUE

When the dentist sets the six anterior teeth, beginning with the basic positions of the central incisors, or when a critique is made at the try-in appointment, the patient should be in a normal standing position. It is extremely difficult, if not impossible, to analyze the dental composition when the patient is sitting in the dental chair. In addition to this, the dental composition should be criticized from a distance of 6 to 8 feet to obtain the over-all effect of the smile. A good procedure is to insert the trial dentures for a try-in and have the patient walk to the door of the operating room, turn around, and smile. This provides the advantage of a sudden impact of a pleasing or displeasing effect, and primary corrections are made from observing the patient at that distance.

CONCLUSIONS

"There are two worlds; the world we can measure with line and rule, and the world that we feel with our hearts and imagination."—Leigh Hunt.

The dynesthetic procedure has been refined in an atmosphere of complete freedom; all restrictions imposed by custom, habit, or personal opinion have been deliberately eliminated in an effort to reach the true answers to each esthetic problem. Therefore, paradoxically, the more experience we have had with the dentogenic concept of esthetic procedure, the less we tended to follow exactly the didactic and arbitrary rules of recognized dynesthetic composition. Dynesthetics are a guide and not a compulsion and, thus, our imaginative perception eventually is given more freedom. However, the rules must be learned first, and only practice in their application will lead to success. No matter how carefully we analyze the factors of the patient's sex, personality, and age, there remains the necessity of translating the soft feminine personality or the hard masculine personality of all ages into the prosthodontic interpretation. The medium is dynesthetics. The combination of this disciplined effort with eventual artistic freedom in our esthetic effort is the ultimate goal.

Today's requirements of professional achievement and public service cannot be measured by yesterday's standards of techniques or materials. Not too long ago, the physician was hardened to accept philosophically the loss of a life from septicemia or a damaged heart valve because of a transient bacteremia. All that has been changed by new knowledge and new medicines which have set higher stand-

ards of accomplishment for even the least practiced physician. Our own standards of patient psychologic comfort have risen too, so that we are now ready to recognize and measure a suppressed personality or a psychosis of dental origin with the same shocked eye that now observes a septicemia, and the same revulsion toward neuromuscular distortion of facial beauty by inadequate prosthodontic intervention as would occur with an unnecessary plastic deformity through inadequate surgical intervention.

The challenge of progress in a rapidly developing and maturing profession such as dentistry has always been met and, in this decade of esthetic renaissance, the reward of success is immediate, exciting, and gratifying.

The technical illustrations were made by Charles W. Matthey and are reproduced from the **Reference Manual,** "A Study of the Dentogenic Concept of Dental Esthetics and Dynesthetics," published by the Swissedent Foundation.

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THE PSYCHOLOGIC CONSIDERATIONS IN DENTURE PROSTHESIS

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THE RECENT EMPHASIS ON the psychologic considerations in all aspects of human behavior has stimulated the dental profession to examine the psychologic and social history of patients and to relate the findings to the clinical practice of dentistry. The profession has responded to this stimulus, has published actively in the periodical press, and has published several textbooks on psychosomatics. The published material on psychology in relation to dentistry has generally alternated between the extremities of (1) a complex representation of the psychiatric terminology and conceptual schemes as represented by several prevalent schools of psychiatry, and (2) an oversimplified presentation of everyday psychologic expression, in which the dentist should employ "common sense," "clinical judgment," and "size up the patient and his needs." The former does not lend itself easily to the clinical practice of dentistry, and the latter adds no real insight to the patient's psychologic state in relation to both his clinical problems and his clinical needs.

This article abstracts a simple unified concept expressing human behavior from the general field of psychiatry and psychology and relates it to the common sense experience and judgment pertinent to the clinical practice of denture prosthesis.

The need to employ the concepts of psychology and psychiatry are limited in dentistry at this time. Nevertheless, when indicated, they are essential for successful treatment. For example, it is important to know *why* a patient wants dentures and to understand the motivation which stimulates the patient to seek dental care. Is it pain, esthetics, or prevention of disease? Another factor of importance is the capacity of the individual to adjust to stress. Is the patient prepared to sit through an extended period of clinical care and to accept both the inconvenience and the responsibility of dental care programming?

Such phenomena as motivation and adjustment are readily determined, and it is not necessary to become involved in the whole psychosocial history of a patient. It is important to elicit just enough information from a patient to expedite treatment. It is both unnecessary and unrewarding to examine the patient beyond the clinical requirements for dental treatment.

Other factors regarding human behavior which are applicable to dental practice in addition to the motivation for seeking treatment and the adjustment to the problems in treatment are (1) the need for active participation of the patient in treatment, and (2) the psychosomatic phenomena.

Received for publication Aug. 12, 1957.

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THE REFLEX ARC

There is a universality about the reflex action governing the relationships between the sensory perception and the motor response. The reflex action is one wherein certain sensory impressions are received and corresponding and appropriate motor impulses are discharged with or without conscious realization.

For every stimulus impressed upon a human organism, there is a direct motor response which depends upon the nature of the stimulus, the nature of the past experience of the organism, and the current activity of the organism. Thus it is inferred that a stimulus is an impression received from the external environment through one of the sensory end organs and conveyed to the brain by the sensory nerves or an internal stimulus arising within the brain from memory or experience which is capable of inducing a motor response.

A motor response is an impulse to activity carried to the muscles and glands of the body through motor nerves. When the impulse is strong enough and is not inhibited or suppressed in any way, it results in a clearly defined muscular or glandular action. However, many of our motor impulses are too feeble to result in any overt or outwardly visible action, and many more are inhibited either consciously or unconsciously by reason of restraints imposed upon us by education. This latter response, which is inhibitory and allows no discernible overt response, nevertheless gives a concealed response which can be recorded in terms of changes in blood pressure, electrical potential, and by other recording devices used for observing physiologic changes in tissue.

In view of these considerations, a dentist attempts to produce the correct motor attitudes in his patient in terms of cooperation, understanding, and learning when he confronts a patient in the treatment procedures for denture prosthesis. The dentist must take into consideration both the nature of the stimulus aroused by each of his actions in the treatment procedure and the previous experience of the patient with dental care. Evaluation of these combined stimuli is essential to the dentist because primary sensory stimuli, such as touch or pain, are in themselves meaningless. It is only as the stimuli take on meaning in terms of an individual's experience that they become significant. The value of stimuli must be learned through familiarity and understanding of their significance in relation to the whole experience of life. Accordingly, dentists, in the treatment of their patients, must be tolerant of deviant responses. They must explain without offending or oversimplifying the nature of their procedures, and they must also attempt to help the patient integrate these new stimuli with his previous experience or lack of experience.

When patients appear for treatment, they come because they have been motivated in some fashion. However, frequently they are not prepared and are not capable of making satisfactory adjustments to the demands of treatment. It is important to understand the relationship between motivation and adjustments in this framework. Such a discussion is perhaps best developed by first understanding the concept of homeostasis.

HOMEOSTASIS

A basic concept for comprehension of cell and tissue behavior is the concept of homeostasis. This term, when employed in cellular behavior, means a tendency

of cells, tissues, and organisms to maintain the constancy of the internal condition or environment which is essential to their well-being such as control over temperature, oxygen, water concentrations, Ph, and other metabolites. In almost all instances when balance is disturbed, automatic function gives rise to drives that stimulate the organism to act so as to restore the needed constancy. Homeostasis, then, represents the principle of adjustment at its most primitive level, the adjustment of the body within itself. This simple principle also applies when the organism must adjust to external stimuli that arise from complex social situations. These are considered adjustments in behavior and express the external relationships between a person and his social environment.

Cell, tissue, and organ activity attempts to maintain equilibrium within itself and in relation to its host with a minimum expenditure of energy and to continue to function and to move in the mainstream of healthy relationships between tissues. Likewise persons function in relation to themselves and to the social structures in which they live. Individuals try to develop behavior which is constant with a minimal expenditure of energy, the avoidance of conflict, and the cohesiveness of behavior which is for the common good. When patient behavior is contrary to acceptable social behavior, the resultant conflict gives rise to conflict not only within the person, but also in the relationship of this person to the social structure.

Patients seek dental care for a number of reasons. Whatever the reasons, the objective is ultimately to achieve the equilibrium associated with homeostasis. Not all patients seek the best possible dental care. On the contrary, most patients seek an intermediary level of care which is consistent with their motivation and their capacity to adjust to a number of psychologic factors, such as frustration, anxiety, fear, and tension.

MOTIVATION

Purposeful human behavior is motivated behavior; that is, there are either physiologic or social stimuli which activate people to do something. The simplest form of motivated behavior is the simple reflex of pain. A sharp pin irritating an infant will stimulate him to cry until relief is provided. The more complex motivations such as thirst and hunger are sustained until they are satisfied by food or drink. These stimuli (pain, hunger, thirst) are sustained and do not usually abate until some action is taken. Thus, persistent stimuli that disrupt homeostasis require an adjusting response and are basic to motivation. It is not to be inferred that single stimuli motivate behavior. On the contrary, motivation at one time is a function of a complex pattern of stimulations, some coming from the internal environment of the body itself, and others from the external environment. Thus, all the inner and outer stimuli that bear upon a person at one time constitute his psychologic (motivating) field and jointly determine his behavior. However complex the pattern or fields may be, it is only persistent stimulation that arouses and maintains behavior. Thus, motivation must be sustained until treatment is completed.

In clinical practice, patients seek dental care for (1) the relief of pain, (2) the prevention of pain, (3) the maintenance of health, and (4) the maintenance and development of appearance. The relationships of the individual to the general social structures determine how he is motivated to care for his teeth, to look well, to speak well, and to prevent the loss of teeth in the absence of pain. Clinically, if a patient comes for the relief of pain, it is inappropriate to discuss at length the need for extensive restorative treatment, even if it is indicated. Such a patient must be relieved of pain, and only as a subordinate issue should an attempt be made to discuss further care. Patients may color their judgment by the pain during a painful experience, and even though they have insight at the moment of pain into the need for dental care, they soon tend to fall back into their general attitudes toward dental care which existed before the onset of pain. Such an attitude may be one of neglect and of seeking only palliative and minimal care.

Extensive education for dental care must thus be developed only in a non-painful situation. The problem of education and motivation for seeking care is complicated in denture service. Patients who are not motivated to seek care for themselves but are yielding to the desires of others may rarely be satisfied denture-wearers, because they are really not convinced of the need for dentures. Thus, they may go through the motions of dental treatment and, frequently, they wear their dentures only when the donor or prodder is in their presence.

Another instance when motivation for dental care is poor is the situation in which patients do not seek care in broad terms of maintenance of health and esthetics collectively but are motivated by very specific and narrow factors. For example, when a patient is concerned solely with the shape and contour of tooth surface or is especially interested in the shade of a complete denture, the dentist may have clinical difficulties in attempting to satisfy the very specific requirements of this patient. These specific requirements should be carefully evaluated when the patient discusses only lip contour, lip creases, nasiolabial folds, and other such cosmetic considerations.

Motivation for dental care is best when it is general in terms of prevention of disease and disability, maintenance of health, and an acceptable level of appearance and speech. Motivation for dental care is poor when it is exclusively specific and when it is directed only to one aspect of treatment. The consequence of narrow motivation in denture prosthesis is manifest in the inability and unwillingness of the patient to learn the skills for successful denture-wearing and to make an adjustment in accepting the reduced functional activity of the artificial dentures.

ADJUSTMENT

Cellular and tissue changes create the needs which the tissues must satisfy in order to recreate the conditions of equilibrium or homeostasis by exchanging metabolites, eliminating wastes, and absorbing oxygen and nutritional elements. Thus, life consists of a series of such sequences in which needs are aroused and then satisfied. This familiar pattern is the process of adjustment or adaptation.

The process of social adjustment is quite similar. Most people want to be recognized and approved by their fellow men. When someone is criticized for poor

speech or poor appearance because of missing teeth, that need is thwarted and there is disharmony between the desire and the ability to fulfill it. There is thus need for adjustments to gain social approval, and the thing to do is to obtain dental care and thus achieve social approval. This is one form of adjustive or adaptive behavior.

However, another form of adjustment is to make excuses, to belittle the critics, or to avoid the critics and associate only with the people who also have poor dentitions. This latter response does not bring broad social approval but tends temporarily to reduce the distress that some people may suffer. Thus, both physiologic and psychologic adjustments, in an attempt to retain equilibrium, have degrees of adjustment. When cells do not achieve maximal adjustment, they perform with reduced efficiency, just as people do when they are deprived of maximal adjustment to new conditions. There is, however, one critical difference between adjustment to the physiologic needs and adjustment to social needs. The only successful adjustment to oxygen want, hunger, or thirst is to breathe, eat, or drink. Compromise below threshold needs is impossible, and complete deprivation results in pathosis and death. However, when one fails to achieve social adjustment, he remains alive and keeps on trying and living even though the adjustment is inadequate and presents a continuing personal and social problem.

This distinction between physiologic and psychologic adjustment explains the difference between seeking treatment for an infected tooth which is painful and seeking treatment for an edentulous situation. The former creates an urgent physiologic motive for treatment which, if not resolved, may conceivably lead to death. The latter, although frequently associated with nutritional problems, is more frequently associated with social phenomena. Hence, people seek relief of toothaches almost universally under any economic and social situation, but millions of people in the world are edentulous or partially edentulous. These people lack the motivation or adjustive capacity for many reasons and so continue to live and to accept or seek the lesser or alternate forms of adjustment.

CONFLICT AND FRUSTRATION

In denture prosthesis, the questions of adjustment and motivation must be analyzed in terms of the patient's ability to resolve conflicts and frustrations. For example, once a strong motive is aroused to achieve dental care, it tends to keep the patient in continued motivated activity until treatment is accomplished. However, when a patient cannot organize his affairs to provide time for treatment, if the motive for dental care is inhibited by some personal relationships, or if poor rapport exists with a dentist, the patient does not make an appropriate adjustment to achieve care.

Another problem in adjustment comes from frustration on the part of the patient. Sometimes tissue pathosis creates clinical difficulties which limit the nature of treatment, and the patient has unrealistic expectations, making him incapable of accepting less than an idealized version of his appearance. In such

instances, the adjustive capacity of the patient is not good. Frequently, treatment is unduly prolonged and not completed and is interrupted with resentment toward the dentist.

LEARNING

The principles of adjustive processes have been described as a sequence of behavior patterns by which organisms overcome obstructions and resolve conflicts. This sequence is regarded as a learning process. Some aspects of learning are associated with conditioning or associative learning, or, as it is called, "trial and error learning." In all instances of learning during the technical procedures and in learning to use the completed denture, the patient's *adjustive* capacity must be optimal.

Motivation and adjustment are both essential ingredients of the patient's behavior in denture service. They are separate phenomena but cannot be separated in life. For example, the best motivated patient may present an ideal morphologic situation, but if he is easily frustrated and has many personal conflicts, he does not generally present a satisfactory treatment situation. On the other hand, a patient who is well motivated, who presents an unfavorable clinical picture, but who is a stable and well-adjusted individual, provides a favorable clinical situation.

PATIENT'S PARTICIPATION IN TREATMENT

A well-motivated and properly adjusted patient generally enters the dental treatment experience with a sense of responsibility to the dentist with regard to the demands upon his time, his facilities, and his training. He recognizes the limits of dental science. Such a patient expects treatment to provide and maintain a state of health and to provide a relative increase in comfort, function, and appearance. He accepts the limitations of the artifacts which we call dentures and he does not expect them to duplicate nature in form or efficiency. He is prepared to accept less than an absolute and frank duplication of nature.

The poorly motivated patient is one who does not adjust readily to problems; he frequently makes unrealistic demands upon a dentist's skill and facility; he does not share responsibility for his symptomatology, and he will not share in the responsibility for decisions during treatment. For example, it is not uncommon for patients to want certain shades or forms of teeth and to insist literally that the dentist comply against his judgment. Further, upon completion of a service which turns out to be unsatisfactory, such a patient frequently places the responsibility on the dentist for the final outcome.

There is also the overcomplaint patient who says, "Do as you wish, Doctor, you are the dentist," and who says no word or comment during the treatment. However, when adjustments are necessary, he complains that there should be no reason for adjustment. There is also the patient who tries to be too cooperative and anticipates every step that involves tissue activity. This creates tension in postural positions which will mitigate against successful impression or recording procedures.

Many other instances could be cited concerning the degree in the manner in which patients do or do not participate in the treatment.

Participation does not imply that patients should hold impressions while the crystallization of impression materials takes place, or that they should do errands or be abused by undue waiting time before treatment. It implies sharing judgment, giving honest histories, not distorting symptoms, acknowledging proper financial responsibility, and showing respect for the dentist's time and facilities. A well-motivated, adequately adjusted person who has a sense of responsibility and is aware of participation in treatment, permits the most satisfactory treatment experiences in denture prosthesis. Less than an ideal patient's personality syndrome generally provides the basis for less than satisfactory treatment results. A careful evaluation of a patient's behavior syndrome, coupled with his biophysical findings, aids considerably in the evaluation of a prognosis.

PSYCHOSOMATICS

It has been generally accepted in medicine and dentistry that psychologic conflicts play a role in the development of tissue alteration and subsequent tissue pathosis. Some diseases have become identified as psychosomatic disorders when the contributing psychologic component is the dominant etiologic factor. The term "psychosomatic" implies the dual character of the disease, wherein the patient's mind, his psyche, determines the character of the disease of the body. This relationship has been described by the psychiatric classification scheme of the army and by others, as the somatization reaction. These reactions are characterized by two factors: (1) they are initiated by interaction between psychologic factors, and (2) they cause tissue alteration and pathosis to the structures of the body.

These psychosomatic disorders generally involve all the major functional systems of the body; i.e., the digestive, circulatory, respiratory, glandular, or reproductive systems. The character of these functional systems which are essentially visceral, involve all the somatic functions such as locomotion, learned digital skills, mastication, and speech. Thus, any somatic function that can be disturbed by strong emotion can become the basis for psychosomatic disorder.

The link between the mind and the body in psychosomatic disorders can be observed in the visceral systems as a function of the changes in the emotional state of the patient. This link thus establishes the autonomic system as the mediator between the mind and the body in psychosomatic disorders. Patients who are in a state of emotional crisis present symptoms involving the circulatory, the digestive, and the excretory systems. However, in a normal, peaceful, vegetative existence, the parasympathetic components of the autonomic system keep the patient in a state of equilibrium or homeostasis. When a strong emotional state is established, either because of some danger in the environment or some psychologically induced stimulus, a state of stress is established, and the sympathetic system thus dominates. For example, if the emergency requires physical effort, an increased heartbeat stimulates more blood volume circulation, providing an increase in the rate of exchange

of metabolites in the skeletal muscle. The body thus mobilizes its circulation for the creation of energy for musculoskeletal activity. However, simultaneously with the sympathetic action upon the blood flow to the muscles is the reciprocal action of the parasympathetic nerves which normally provide abundant blood flow to the digestive system. Thus, it is apparent that the relative volume of blood supplied to the digestive organs decreases and that the blood supplied to the skeletal muscles increases. The whole complex of digestive symptoms, therefore, is due to the shift from the parasympathetic facilitation of the digestive system to the sympathetic inhibition of the digestive processes. The deprivation of the blood flow to the digestive system gives rise to a host of functional disorders which ranges from the oral cavity throughout the entire gastrointestinal tract. The most common disorders which affect prosthodontic treatment are: (1) circulatory disturbances, (2) respiratory disorders, and (3) gastrointestinal disorders.

Circulatory Disturbances.—Changes in the function of the circulatory system are among the most constant of the physiologic aspects of emotion. The common problems of hypertension, vasomotor instability, and cardiac disease, play a role creating functional difficulties in mastering a high level of performance in denture function. However, there are also nutritive deficiencies when circulation to the mucous membrane is altered by depression during an emotional disturbance. The poor circulation provides poor resistance to abrasion with resultant ulceration of the mucous membrane which is in contact with the dentures.

Respiratory Disorders.—A common physical complaint in psychosomatic patients is shortness in breath, or difficulty in breathing. Respiratory changes are a prominent feature in intense emotional states. Frequently, asthmatic attacks are encountered. In denture prosthesis, the manipulative procedure during impressions and jaw recordings frequently cause shortness of breath, gagging, and retching. Patients who gag readily must be firmly but sensitively treated, for generally the clinical problems associated with gagging are essentially psychologic in character. Every effort must be made to provide easy, comfortable breathing during treatment. Attention must thus be directed to providing a patent airway by good chair posture, by bringing the head forward so that gravity carries salivary fluids and impression materials forward out of the mouth, and by firm sympathetic management. Patients should be directed to breathe slowly and deeply and with a regular rhythm.

Gastrointestinal Disorders.—Gastrointestinal disorders associated with emotional changes have a long history. The oral structures are part of this system and just as several divisions of the gastrointestinal tract have psychosomatic disorders appropriate to their tissues, so does the oral cavity.

An increase in the bacterial flora of the mouth: Poor hygiene frequently is associated with psychoneuroses and causes interference with circulation and antibody formation of the saliva. Faulty diet is frequently nondetergent in character and, coupled with poor masticatory efficiencies, promotes and hastens bacterial growth. Patients who are in a depressed state provide little oral hygiene for themselves, and they may allow masses of debris to accumulate in the buccal folds and on denture surfaces.

Habits which are detrimental to alveolar bone and mucous membranes: There are numerous habits, such as pencil-biting, nail-biting, lip-biting, cheek-biting, tongue thrusting, tooth tapping, tooth clenching, and grinding. These habits are associated with neuroses and frequently cause rapid changes in alveolar bone, ulceration of the epithelium, and very frequently ill-defined pain.

Unfavorable dietary intake: Some patients very frequently eat unduly seasoned food because of cultural habits. Other patients may have a poor selection of diet either by choice, because a good diet is not available, or because they have poor masticatory function. Patients under tension frequently ingest large amounts of candies, cakes, alcoholics, and frequently smoke excessively. These excesses inhibit ingestion of a good diet which is essential for the maintenance of healthy mucosa and alveolar bone.

CONCLUSION

Human behavior is dictated by bodily and social needs. These needs are directed by the principles of equilibrium or homeostasis, wherein man attempts to maintain a stable physical and psychologic state of being. His behavior is motivated by stimuli which constantly stream from the external and internal environment. The appropriate responses to these stimuli are the adjustments and adaptations which maintain the stable state of being. Fear, anxiety, tension, and frustration are inhibiting factors which may prevent a satisfactory adjustment toward equilibrium and which may abort the optimal adjustment. When patients are well motivated to come for treatment, they may inhibit all these deterrents, and thus they may make an appropriate adjustment for receiving dental care. However, patients frequently have personality aberrations which manifest systemic diseases or symptoms. These psychosomatic problems create difficulties in dental care. In denture prosthesis, they frequently create conditions which, if the psychoneurosis is not revealed, cause clinical difficulties which mitigate good dental service. Thus, we see that for psychologic reasons the difficulties which arise in care may range from functional difficulties in which functional symptoms involve a vicious psychosomatic circle starting with emotional reaction, conflict, functional derangement of organs expressive of emotional conflict, more emotional reaction, more functional incapacity, and so on, until the human machine runs down and there remains a structural pathology. This pathology is the diseased or altered tissue which we find upon examination of the patient. It behooves the dentist, thus, to develop insight into the character of this vicious cycle in order to achieve optimal dental care for his patients.

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ORAL CONDITIONS ASSOCIATED WITH DENTURES

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EVERY DENTIST WHO HAS made a denture for a patient is familiar with some form of sore mouth associated with the wearing of dentures. Practically every new replacement has an adjustment period during which the tissues in contact with the denture base become irritated. In most instances, one or two adjustments will correct the condition by removing the cause. On the other hand, we are confronted at times with lesions that are more persistent. Certain pathologic conditions of the denture-bearing area may make it extremely difficult for patients to tolerate well-constructed dentures. The recent trend has been to a biologic approach to the denture problem in contrast to the more mechanical approach of a few years ago. We finally have come to realize that the mechanical and biologic phases are closely related, and they must be considered as components of one and the same treatment.

CLASSIFICATION OF LESIONS

Since the rationale of good treatment is to remove the cause of the pathologic condition, we might classify denture-associated lesions by their causes. The first group would be those lesions caused by the dentures. The second group would be those lesions resulting from some other cause. In the second group are conditions which, while not primarily caused by the dentures as such, are to some extent aggravated by them.

LESIONS CAUSED BY THE DENTURE

Irritative Lesions Caused by the Denture Flanges.—The great variations in the philosophies of the design of complete dentures embrace practically all the possibilities of design. According to the mucostatic philosophy, it is felt that the denture borders should not contact the soft tissues of the mucobuccal fold for a border seal. Forces other than atmospheric pressure are depended upon to retain the dentures. The reasons are that dentures constructed in this manner make the patient less aware of the dentures, and the elimination of pressure in the posterior palatal seal area eliminates the formation of decubital ulcers from local interference with circulation. It is possible that dentists following the mucostatic philosophy accomplish their purpose, but all techniques have disadvantages as well as advantages. It seems that this design might sacrifice stability and retention which would result in

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The opinions and assertions contained in this article are the private ones of the author and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large.

Received for publication Aug. 16, 1957.

increased movement of the denture bases, and irritative lesions might then be caused in areas other than at the denture borders.

Experimentation has shown that denture retention is greatly enhanced by the use of a border seal established by finishing the margins of the denture in soft tissue and with a posterior palatal seal.[1] Consequently, most complete dentures are constructed with an attempt to accomplish this objective.

We are faced with the individual differences between patients when we are dealing with tissue tolerance. Unfortunately, what is tolerated by the tissues of one patient may not be tolerated at all by the tissues of another patient. It then becomes difficult, if not impossible, to predetermine the exact amount of pressure to introduce in the placement of the denture border tissues. More often than not, when new dentures are inserted, we find slight ulceration in the denture border regions after the dentures have been worn for a day or so. Fortunately, this condition is easily corrected by relieving the tissues from the excess pressure of the denture in the area of the lesion. Because dentures have a tendency to settle, these pressure ulcers may appear after the patient has been wearing the dentures for some time.

Epulis Fissuratum (Granuloma Fissuratum).—When the residual alveolar ridge resorbs, a space may develop between the denture and the supporting tissue, usually in the labial region of either the maxillary or mandibular denture, and there may be a tendency for this space to become filled with hyperplastic tissue. This tissue is called an epulis fissuratum if it occurs in certain forms (Figs. 1 and 2). The constant pressure and movement of a denture, which has become unstable because of the ridge resorption, may cause the lesion to ulcerate. The epulis fissuratum often seems to result from the comparatively rapid resorption which sometimes follows the insertion of immediate dentures. Associated with an immediate denture, an epulis fissuratum may appear within six months after insertion of the denture. However, it usually appears after a patient has been wearing a denture for many years without service. Although this lesion seldom becomes malignant, it is mistaken sometimes for a malignant lesion. There are a number of differences that will help in the differential diagnosis. The swelling is usually edematous, although it may be firm, and there is usually no odor or adenopathy, and it is not associated with leukoplakia.[2]

If the patient leaves the denture out of the mouth for several days, the edema will subside, and the remaining lesion will be considerably smaller. It is usually necessary to remove the residual lesion surgically, and since the lesion is associated with alveolar ridge breakdown, the operation may include ridge extension. If ridge extension is considered, an attempt should be made to avoid the formation of scar tissue in the mucobuccal fold.[3,4] It is better to avoid the ridge extension if the scar tissue cannot be prevented, because scar tissue in the mucobuccal fold will likely interfere with the border seal which would result in diminished retention.

IRRITATIVE LESIONS CAUSED BY THE BASAL SEAT OF THE DENTURE

Occlusion.—A surprisingly high percentage of complete dentures are constructed with the centric occlusion not in harmony with the patient's centric re-

lation. When complete dentures are constructed with cusp teeth and with this error, the teeth occlude inharmoniously, causing the denture bases to tend to skid or rotate on the tissues every time the patient brings his teeth together with the jaws in centric relation. This occurs at least every time he swallows. In some instances, this causes an inflammatory reaction which varies in intensity with the amount of denture movement and the patient's tissue resistance. The inflammation, if intense enough, will stimulate an osteoclastic reaction which results in a more rapid breakdown of the residual alveolar ridges which, in turn, increases the error in occlusion. Thus, a vicious cycle is established which will continue for an indefinite period of time, depending on the patient's psychologic adjustive mechanisms.[6] The result is a stomatitis if the patient has a predisposing systemic condition (Fig. 3).

Fig. 1.

Fig. 2.

Fig. 1.—An epulis fissuratum which is caused by the constant pressure and movement of a denture. The denture had become unstable because of ridge resorption. Epulis fissuratum is often associated with immediate dentures that have not had proper service, and it is usually found in the cuspid regions.

Fig. 2.—An epulis fissuratum may become ulcerated, but this ulceration is not always present in this condition.

Relief Areas.—Because there are differing thicknesses of soft tissue covering the bone of the denture-bearing area, and because complete dentures move in function, it is necessary to relieve certain areas of the basal seat of the denture. The purpose of this relief is to allow for the movement of the denture without irritation

to the areas that are less thickly covered with soft tissue and to prevent interference with the nerve and blood supply when they are close to the surface. Formerly, it was believed that relief chambers (sometimes called vacuum chambers or air chambers) enhanced retention and often they were used indiscriminately for that purpose. Relief areas not only do not add to the retention of dentures, but they interfere with it by allowing the formation of a thicker fluid film in the space created by the relief. The thinner the fluid film, the better the retention.[1] Plastic denture bases allow for a scientific approach to the relief problem, because the variation in the thickness of the soft tissue can be measured during function by the use of disclosing wax. With metal bases, we must depend more upon our judgment for the depth of the relief.[5]

Fig. 3.—Irritation and alveolar ridge breakdown resulting from an unbalanced occlusion.

If the relief is too great, it is likely to cause edema and hypertrophy of the mucoperiosteum. A "negative" pressure is probably not constantly present because the relief area will usually be filled with fluid, but it is likely that there will be an *intermittent* "negative" pressure. This might irritate or stimulate the tissue and result in inflammation or hypertrophy. It may also irritate the small palatal mucous glands and cause them to enlarge and produce a nodular surface in the relief area.

Stomatitis Venenata.—This condition results from the contact of causative agents with sensitized oral tissue. There is a burning and redness of the mucous membrane of the basal seat of the denture with possibly a vesiculation and sometimes a severe glossitis. This type of reaction has been reported as resulting from some denture base materials used in the past.[7] It is not likely to occur with acrylic resins if they have been properly cured. However, there have been cases of stomatitis venenata which apparently have been caused by impurities in the resin or by plasticizers that are incompatible with the tissues of the mouth. Certain chemicals, such as the essential oils, especially eugenol, attack acrylic resin, and these drugs are used in mouthwashes and dentifrices. A patient who has not been instructed concerning this incompatibility may clean or soak his denture in one of these preparations. This cleaning could change the chemical composition of the surface of the denture base, and the resulting substance could be irritating to the oral tissues.

The situation may be different with the autopolymer resins, because their physical properties indicate that they have an incomplete polymerization which would allow some free monomer to remain in and on the surface of the denture base. It is not uncommon for patients to be sensitive to free acrylic resin monomer. Apparently, it is a toxic substance.[8,9]

Practically all denture repairs are made with the autopolymer resins in an effort to prevent the marked dimensional change that takes place in the denture bases when they are cured and recured. If a patient becomes sensitive to a denture after a repair, it might be well to consider the repair material as a possible causative agent.

If sensitivity to a denture base material is suspected, scrapings from the denture may be placed beneath an adhesive bandage on the arm and allowed to remain there overnight. If the patient is sensitive to the base material, there probably will be a small inflamed area on the skin.[10] The scrapings should not be allowed to remain on the patient's arm for a longer time than overnight, because an undue inflammatory reaction on the arm would result if the patient is sensitive to the material.

Denture Sore Mouth.—This is a term given to an inflammatory stomatitis. The tissue immediately beneath a denture becomes highly inflamed, and the inflammation follows the exact outline of the denture. The exact cause is not known for certain, although it seems to be associated with poor oral hygiene. It is possible that the tissues are irritated from toxins or micro-organisms which grow under the denture. This growth seems to be accentuated by improper adaptation of the denture to the tissue upon which it rests.

Burket[11] states that the pH of the secretions under the denture becomes lowered. This acid condition may help to reduce the resistance of the tissues in some patients. Most dentures are constructed of plastics which are good insulators and, consequently, the tissue heat is retained under the dentures. This retained heat might effect the resistance of tissues.

Cahn[12] reports the presence of *Monilia albicans* in a number of patients. It is possible that, with the current use of antibiotics, the bacterial flora of the mouth could be upset, allowing these yeast organisms to invade the oral tissues. Burket[13] reports this to have happened in 9 patients who were treated with chloramphenicol.

In some cases of denture sore mouth, there are white patches that can be peeled off. No ulceration is present, but there may be a tendency to spontaneous bleeding. The most disturbing characteristic of this condition is its persistence. It has been suggested that the patient not wear a denture for from 3 to 6 months[12] and that the infected areas be painted with one of the dyes, such as gentian violet. This may be a satisfactory treatment, but it is difficult to persuade a patient to carry it out.

When the inflammation seems to be extreme in relation to the cause (denture sore mouth), it is well to look into the possibility of endocrinologic control of the inflammation. Many diseases have common features which are general types of reactions or nonspecific features. The common features of disease are closely integrated and represent part of a single response. This response has been called "a general adaptation syndrome." The common feature of infections, trauma, nervous

strain, heat, cold, etc., is the fact that the body is placed in a state of systemic stress. One of the symptoms of this stress is adrenocortical enlargement. The stress sets up what Selye[14] calls "an alarm reaction" which is transmitted to the anterior lobe of the pituitary body causing it to secrete adrenocorticotropic hormone (ACTH) which in turn stimulates the adrenal cortex to produce two groups of corticoids, one antiphlogistic and one phlogistic. They in turn control the intensity of inflammation. Inflammation is a defensive reaction. Therefore, indiscriminate use of these hormones as therapeutic agents could produce dangerous side effects. However, 0.05 per cent hydrocortisone acetate in a denture powder base will clear up the symptoms of denture sore mouth in several days. If the patient's denture is satisfactory, it can be used to keep the medication in contact with the inflamed tissue. The powder is placed in the denture at 8-hour intervals during the day. The denture is left out at night and placed in an antiseptic solution for decontamination. A chlorinated solution made from calcium hypochlorite or washing bleach (Clorox) is quite satisfactory for this purpose.

Although recovery with this treatment is dramatic in comparison to other recommended treatments,[12] there is a tendency for the condition to recur if sterilization of the dentures is not continued. There seems to be little danger in the use of 0.05 per cent hydrocortisone acetate for a short period of time with a healthy patient.

Leukoplakia.—Patches of leukoplakia may be covered with dentures, provided the dentures do not irritate the lesions. We might hesitate, however, to put a heavy posterior palatal seal or other border pressure over the lesion of leukoplakia. In mouths of heavy smokers who wear dentures, leukoplakia is often seen surrounding the denture borders indicating that the tissues under the denture were protected by the denture. We should not lose sight of the fact that leukoplakia is considered to be a premalignant lesion and, therefore, it should be observed frequently and treated as indicated.

Burket[16] says galvanism plays no part in the production of cancer. Others[17] feel that galvanism may play a part as a causative stimulus in leukoplakia. In the examination of 15 patients with leukoplakia, it was found that the electrical potential from dissimilar metals was over four and a half times as great in the mouths of those patients exhibiting objective symptoms, as compared with those having no symptoms. The same investigators,[17] through spectroscopic examinations, found metallic ions of silver and cadmium (from dental restorations) deposited in the oral tissues.

ORAL LESIONS THAT MAY BE AGGRAVATED BY A DENTURE

Desquamative Stomatitis.—Fortunately, this is not a common condition. In the advanced stages, the epithelial layers may separate from the underlying connective tissue, and there is a desquamation or loss of the epithelium which usually occurs in patches. One patch seems to heal while the epithelium of another patch sloughs. The color of the tissues is bright red, especially in the regions where the epithelium has been lost. The desquamated areas are very sensitive, and it is not likely that a patient would be able to tolerate a denture over them. The etiology

is unknown, but it is thought to be from an endocrine disbalance, and there is no known successful treatment. Any natural teeth that are present should be maintained since the disease may be present with or without teeth. Extraction of the teeth is of no help in clearing up the disease, and the patient probably will not be able to wear dentures.

SYSTEMIC CONDITIONS CONTRIBUTING TO STOMATITIS

Uncontrolled Diabetics.—A controlled diabetic might be considered as a normal denture patient. However, when the disease is uncontrolled, there is usually considerably more rapid resorption following the removal of teeth, and the tissues are more likely to react unfavorably to denture irritation and pressure. It is during periods when the disease is untreated or out of control that rapid tissue changes take place, and so it is likely that these patients will need more denture service than others to maintain oral health.

Xerostomia.—It has been claimed that a fluid film is necessary for the retention of complete dentures.[18-20] This has been based upon the theory that the primary retention of complete dentures resulted from adhesion and cohesion; others have called it interfacial surface tension. It is probable that these are different ways of expressing the same idea. Skinner,[1] however, indicates that dentures have greater retention without an apparent fluid film. He gave patients large doses of atropine to dry up their salivary secretions. Then he tested the retention of dry denture bases and found that dry bases in a dry mouth had greater retention than the same bases had with a film of saliva between them and the tissues. It is possible that a dry mouth would not materially interfere with retention.

In xerostomia, the mucous membrane becomes glossy dry and roughened, and painful cracks and fissures which bleed easily may develop. This condition is painful, and it is difficult for the patient to wear dentures. The greatest problem is in function because it is extremely difficult for these patients to form their food into a bolus. Without the formation of a bolus, mastication becomes extremely difficult if not impossible. When the dentures move in function, there is no fluid lubricant between them and the supporting tissues, so local irritations result. This is one of the few indications for the use of well-moistened denture powders or for one of the surgical lubricants. Xerostomia, present to some extent in many senile patients, may be caused by diseases of the salivary glands or nutritional deficiencies, notably by a deficiency of nicotinic acid. This can be administered in 50 mg. doses, about 300 to 400 mg. per day.[21] It has been suggested that sialogogues be used, but there is a certain amount of danger in the prolonged usage of these drugs. Pilocarpine might have some adverse effect on the heart, especially if pathosis is involved in it, and neostigmine might cause abdominal pains.

Nutritional Deficiencies.—Nutritional deficiencies can cause stomatitis and can contribute to its cause. Many denture patients are of the older group, and the tendency of older people is to consume less proteins and more carbohydrates. One of the reasons for this change in diet may be that it is more difficult to masticate proteins than carbohydrates with dentures.

The body is composed primarily of proteins, and proteins can be built up only from amino acids. The blood cells, plasma, and almost all the enzymes are protein.

Many of the vitamins, such as thiamine, riboflavin, niacin, and para-aminobenzoic acid, are proteins. The hormones, insulin, epinephrine, thyroxin, and pituitary secretions, all contain the NH_4 radical.[22] Body functions are disturbed when adequate proteins are omitted from the diet. The disturbances are evident within one day and may be severe within a few days.[23]

Walsh[24] states that, while it has not been proved that paradentosis is caused by dietary deficiency, the most frequent systemic factor predisposing to alveolar ridge resorption is a disturbed calcium-phosphorus balance for which low nutrient, high caloric foods and excess phosphates may be blamed.

Bavetta[25] points out that "sterile calories" from sugar call upon the reserve supply of vitamins and minerals and, thus, aggravate degenerative changes in the supporting structures. The mechanics of restorative dentistry may place additional burdens upon tissues and accelerate their damage. As the appliances produce additional injury, discomfort will cause the patient to exert less and less pressure upon them, and the patient finally resorts to only soft food. Thus, a vicious cycle is set up.

Some of the antibiotics cause changes in the bacterial flora of the intestines which interfere with the absorption of some food elements, especially vitamin B.

Psychologic Overadaptation to Dentures.—For psychologic reasons, some patients do not seek adequate service for their dentures, and damage to the denture-supporting structures is to be anticipated. These patients seem to deny to themselves the fact that an unsatisfactory condition exists about their dentures. Their reasons seem to be an effort to avoid anxiety which may be engendered by their interpersonal relationships with the dentist or with the necessity for adjusting to a change to new dentures. In avoiding the necessary service, many of these patients bring about undesirable changes in the tissues supporting their dentures.[25]

SUMMARY

There is no royal road to successful dentures because not all conditions relating to their success are within the scope of our treatment. We must recognize those conditions which require the service of those who are more skilled in handling the basic medical problems. We should treat those conditions which we are trained to care for and should refer patients who require treatment beyond our field. But, most of all, we must learn which are which.

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STABILIZING THE LOWER IMPRESSION WHILE RECORDING THE PERIPHERY IN FUNCTIONAL POSITIONS

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COUNTLESS TECHNIQUES FOR MAKING impressions of lower edentulous ridges have been proposed and used during the past quarter of a century. These procedures have been evaluated by Swenson,[1] Pryor,[2] Boucher,[3] DeVan,[4] Colburn,[5] Bohannan,[6] and others.[7]

REVIEW OF LOWER IMPRESSION TECHNIQUES

Impression techniques can be classified as being either open-mouth or closed-mouth impressions and further classified by the impression materials or combinations of impression materials used. The following impression materials are available: (1) modeling plastic, in a range of molding temperatures, (2) modified plaster of Paris impression plaster, (3) mouth temperature waxes, (4) impression pastes, in a wide range of fluid and semifluid consistencies, (5) activated acrylic resin impression materials, (6) hydrocolloids, both reversible and irreversible, and (7) the rubber base and silicone impression materials.

Some techniques and materials, particularly the thermoplastic materials, permit a limited border molding by the lingual tissues. Other materials are quick setting and permit only one quick molding *at the particular level to which the floor of the mouth may be raised at the time.* Still other techniques, recognizing the fact that lingual border molding is inadequate and that tissue levels are ever-changing, resort to the use of arbitrary trimming of the lingual flange of the lower denture (McGrane, Mucoseal). Swenson[1] states, "The acceptance of a certain combination of methods and materials known as a technic is not necessarily a solution. Achieving success requires knowledge of and experience in the *application* of the materials and methods that have been chosen. Too many men want the mere acceptance of a technic to secure immediate results."

Dentists today are making lower impressions by one of the following methods or a modification thereof: (1) a full plaster technique, (2) plaster wash impressions in a relieved modeling plastic tray, (3) mouth temperature wax impressions in a modeling plastic tray, (4) full modeling plastic impressions, (5) modeling plastic impressions with wax borders, (6) activated acrylic resin

Read before the Southeastern Academy of Prosthodontics meeting in Atlanta, Ga., March 15, 1958.
Received for publication Aug. 24, 1957.
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impressions in individual trays, (7) fluid wax impressions in individual trays, (8) zinc oxide and eugenol paste impressions (ranging from the so-called 'mucostatic' pastes which offer little or no resistance to tissues, to the stiffer pastes that place tissues in proportion to the coverage afforded by the tray), (9) full alginate (irreversible) hydrocolloid impressions in stock trays, (10) alginate (irreversible) hydrocolloid impressions in individual trays, (11) agar (reversible) hydrocolloid impressions in individual water-cooled trays, and (12) rubber base and silicone impressions in individual trays.

LIMITATIONS OF MATERIALS AND TECHNIQUES

The open-mouth impression techniques are far more widely accepted today than the closed-mouth techniques. Static impressions are favored over pressure, semipressure, and controlled-placement techniques. Each impression technique records the soft tissues in a different form, as influenced by the consistency of the material used and the extension of the tray. For example, at one extreme we have the mucostatic paste impression or the alginate impression made in an underextended tray, which records the soft tissues in their relaxed and nonfunctioning form with tissue folds and wrinkles recorded in the form and pattern they may happen to be in at the time the impression material sets. At the other extreme, we have the correctable wax impression which, because of the coverage of the tray and the ability of the wax to place soft tissue, records the soft tissues in their smoothed-out form, or presumably the form that provides the best support for functioning stresses with the widest areal coverage. Between these two extremes are the majority of impression techniques which record the tissues in their relaxed but placed form, as influenced by the size of the tray and the consistency of the recording medium. It is doubtful that any impression, with the possible exception of the correctable wax impression, can be duplicated for a given individual at a given time, since *all others record the tissues in the position they are in at the time the impression material takes its initial set, and this position is influenced by the many factors of the moment.*

The factors which influence the position of the soft tissues at the time they are recorded, in addition to the size of the tray and the consistency of the recording medium, are: (1) the head position, (2) the influence of the headrest support, (3) the support given to the patient's back by the dental chair, (4) the tenseness of the patient during the time the impression material is in the mouth, (5) the temperature and taste of the impression material, (6) the degree of mouth opening, (7) the amount of movement permitted accidentally or by direction, (8) the position of the tongue, (9) the presence and consistency of the saliva, (10) the bulk and occlusal height of the impression tray, (11) the pressure exerted by the dentist in stabilizing the tray, and (12) the size and position of the dentist's fingers as he stabilizes the tray.

The *size of the tray and the consistency of the recording medium* are within the control of the dentist, since he has a wide range of materials and concepts of tissue coverage from which to choose. He is privileged to use that material and technique which, for him, gives the best results.

Patient tensions usually can be aborted by the use of muscle-relaxing and tranquilizing drugs. Saliva likewise can be controlled by the preoperative administration of atropine-containing drugs. Patient cooperation can usually be assured through the use of preparatory exercises[8] and prior instruction.

There remains to be eliminated or improved upon the influence of the stabilizing pressures and the presence of the dentist's fingers in the patient's mouth, as well as the more physiologic positioning of the patient's head, free from the unnatural influences of the dental chair.

STABILIZING THE LOWER IMPRESSION TRAY

Strangely, to my knowledge, no mention has ever been made of the size or placement of the dentist's fingers in stabilizing the lower impression tray. It has been suggested that finger stops be used, but these have the disadvantage of adding still more bulk to the tray and further restrict physiologic movement.

The patient needs to be freed of all unnatural influences and free to move the tongue and cheeks without restriction. The patient's head should be erect in the normal physiologic position, as described by Brodie[9] and Thompson,[10] with all supporting musculature in balance. This is virtually impossible in the dental chair with its supporting headrest and the tendency of the dentist to recline the patient for his own convenience. Yet, without the support of the headrest, it is difficult, if not impossible, for the dentist to stabilize an impression tray in the mouth with his fingers while the head is being supported by musculature alone.

All open-mouth impression techniques have this one thing in common: the impression tray is stabilized by the dentist while the tissues are being recorded in whatever state the procedure dictates. Likewise, there is almost universally a second factor, which is the postural influence of the dental chair. Also, a third factor, obstacles to free tongue movement, is present in all techniques.

EXTERNAL STABILIZATION OF THE LOWER IMPRESSION TRAY

With the elimination of these factors in mind, the following procedures have been tried with rewarding success. These procedures should not be considered as a technique, for a technique alone does not insure success. Nor should it be considered a gadget to do something for the dentist which makes a successful lower impression easier or guaranteed. Rather, the procedures should be considered as a method for accomplishing something that has not been possible by conventional means. It involves the stabilization of the lower impression tray externally, while the patient and the impression medium records, with a minimum distortion, the form of the tissues upon which the completed denture will rest and by which it will be supported.

Intraoral hinge devices must be discarded as offering as much or more interference to physiologic movement as the dentist's fingers. Gravity alone is either insufficient or too great depending upon the weight of the tray, the degree of extension of the tray, and the resistance of the impression medium.

RATIONALE FOR AN EXTRAORAL STABILIZING DEVICE

The acrobat hanging by her toes from the trapeze bar can do so only because her body weight is centered directly beneath the bar. The lady's purse

hanging securely beneath the bridge or dining table does so for the same reason: the weight of the purse is directly under the bearing surface above and connected to it by a curved rod. The same principle is used to stabilize the lower impression tray while the patient goes through previously rehearsed muscle movements.

The stabilizing device is shown in Fig. 1. It consists of a twelve gauge silver alloy wire to which a lead weight is attached. The weight needs to be sufficient only to keep the tray in place. It replaces the finger pressure ordinarily used and weighs approximately 175 Gm., which is apparently the minimum weight which will prevent movement of the tray. In some instances, a 200 Gm. weight has been used without evidence of overloading. The weight is located beneath the bearing points which are applied to the anteroposterior center of the impression tray on each side.

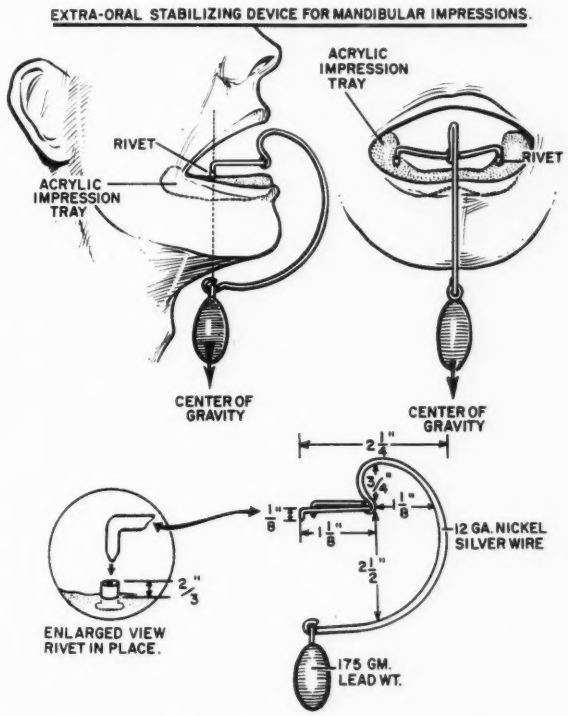

Fig. 1.—The extraoral stabilizing device rests upon rivets which are attached to the tray at the anteroposterior center on each side of the tray. The lead weight is just heavy enough to prevent movement of the tray. Note that the weight is located directly beneath the bearing points which are centrally located on each side.

TECHNIQUE

An accurate border-molded impression is made in modeling plastic in a cut-back aluminum tray. It is most essential that this tray supporting the preliminary impression material be trimmed short of all muscle attachments, so that the

modeling plastic may be freely molded without interference. An overextended preliminary impression will result ultimately in an overextended acrylic resin tray and one that lacks the necessary accuracy. A plaster of Paris cast is poured in this preliminary impression, and the limits of the acrylic resin tray are carefully outlined upon it with an indelible pencil. Undercuts must be blocked out with a material, such as wax, clay, or wet asbestos. Spacers as such need not be used, but the crest of the ridge and the hard bony slopes of the residual ridge should be relieved about the equivalent of 26 gauge thickness or about 0.015 of an inch.

A thin coat of tin-foil substitute is painted over the surface of the cast and allowed to dry. Then, an acrylic resin tray is built up by the sprinkling method, using a very fine self-curing polymer and a 12-minute activated liquid. The thickness of the tray should be uniform and held to the minimum acceptable for strength. If preferred, a rolled-out dough technique may be used instead of the sprinkling method. The sprinkled tray is preferred because of its accuracy and because the tray can be made less bulky.

The acrylic resin tray is placed in a covered dish or covered with an inverted bowl until it has set, and then it is lifted from the cast. The indelible pencil marks will have transferred through the separating medium to the acrylic resin sufficiently to allow accurate trimming to the previously outlined border. The tray is not polished.

The resulting impression tray is tried in the mouth and adjusted to eliminate overextension. All notches for the frenula are widened and extended so as to avoid any tissue impingement during extremes of movement. The tray is extended distally to cover the retromolar pad and into the retromylohyoid space with stick modeling plastic, if necessary. Tongue movements into the buccal vestibule and anteriorly usually will indicate the need for reducing the lingual flange of the tray to avoid any overextension during extreme tongue movements.

When the adjustments to the tray are completed, the borders should be rounded and any modeling plastic additions lightly relieved.

A point directly above the anteroposterior center of the bearing area on both the right and left sides of the tray must be determined and marked with a pencil. One 4-4 brass brake shoe rivet, with its head down, is attached at each of these points to the acrylic resin tray by means of acrylic resin. This can be done by either the brush or sprinkling method. This procedure leaves the hollow tube of the rivet projecting approximately one-fourth of an inch above the tray to receive the bearing point of the stabilizing device (Fig. 1). This is necessary to secure the device and prevent its slipping during the functional movements, especially those of the tongue which are quite powerful. The patient should be cautioned and rehearsed in keeping all tongue movements within the limitations of the stabilizing weight being used. The objective is to record functional but not excessive peripheral tissue movements.

IMPRESSION MATERIALS

No specific impression material is recommended for this procedure. The metallic oxide and eugenol pastes, plaster of Paris, and mouth temperature

waxes have all been used with varying degrees of success. However, the rubber base impression material, to which a retarder has been added, provides ample time for border molding, and yet it sets sufficiently hard for handling without distortion after being removed from the mouth.

Metallic oxide and eugenol impression pastes and impression plasters are displaced too readily and do not permit border molding because of their setting characteristics. Most of the mouth temperature waxes do not flow under the pressures being used, but where greater loading is used, they continue to flow as long as they remain in the mouth. One resinous wax in particular has been

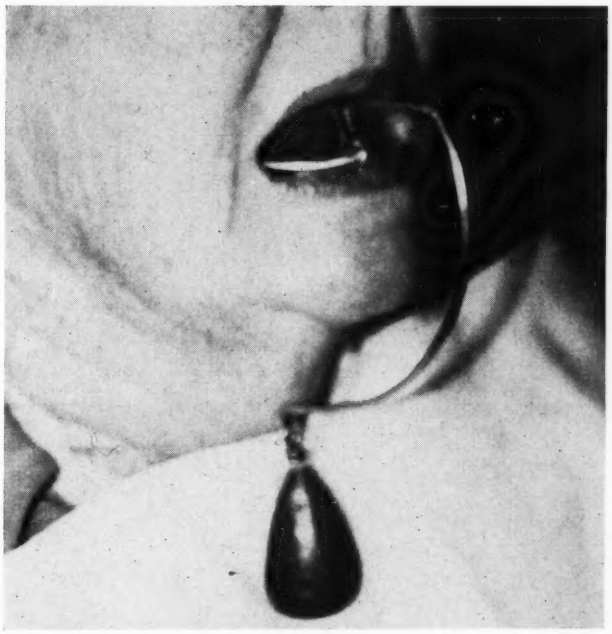

Fig. 2.—The extraoral device attached to the tray. The anterior part of the intraoral arch is free to balance on the two bearing points, permitting face, lip, and tongue movements as outlined in the text.

found to be most satisfactory as an impression material. These waxes are, of course, delicate to handle in the laboratory. A combination impression of impression paste with a wax border has been used satisfactorily, although there is evidence that such an impression is slightly overextended as compared to the wax and rubber base impressions.

The patient is seated comfortably on a stool, having received instructions as to what is expected of him and having been rehearsed through a "dry run" of the procedure. The lips and face are coated with petroleum jelly, and the mouth is packed with three or more 2-inch by 2-inch gauze sponges to absorb any saliva which might accumulate while the tray is being loaded.

The tray is loaded with the impression material of choice, the gauze sponges are removed, and the loaded tray is quickly inserted and seated in its terminal position. Immediately, the points of the stabilizing device are dropped into the

Fig. 3.—A final rubber base impression. The tissue surface detail is accurately reproduced, and the border molding has been accomplished by physiologic tongue and cheek movements.

Fig. 4.—A mouth temperature wax impression. This is one of the more resinous waxes which, because of its flow characteristics, has proved to be a very satisfactory material. However, the cast must be poured immediately with considerable care to avoid distortion.

brass tubes projecting upward from the impression tray. The lower lip is freed, and the patient begins the rehearsed muscle movements. The patient must be sitting upright with the head supported physiologically, and the lip and tongue must not be impinged upon by the intraoral part of the stabilizing device (Fig. 2). The muscle movements are simple: (1) the tongue is placed into the left

cheek, (2) the tongue is placed into the right cheek, (3) the tongue wets the corners of the mouth, (4) the tongue wets the upper lip, and (5) the mouth is opened as wide as possible.

These movements are repeated in that sequence until molding has been completed or the material has passed a molding stage. In the latter case, the impression should not be removed from the mouth until sufficient setting time has elapsed. When a wax has been used, it should be chilled before removal. The stabilizing device with the attached impression is then removed, and the stabilizing device is disengaged.

All of the surface details of an ideal impression should be faithfully recorded on the finished impression (Figs. 3 and 4). In addition, an impression has been made with its border molding unhampered by the restriction of unphysiologic influences. The borders of the completed dentures will be in harmony with all physiologic movements of the border tissues, except those of mastication and deglutition, and these will be influenced to a large extent by the degree of occlusal harmony obtained on the completed denture.

SUMMARY

A method has been described which permits the accurate and physiologic border molding of the lower impression, in harmony with unencumbered tongue and cheek movements. This is accomplished because:

1. The patient is erect in a physiologic posture without the influence from a headrest or a back support.

2. The dentist's fingers have been taken from the mouth while the borders are molded, thereby eliminating their influence upon tongue, cheek, and lip movements, and upon the normal positioning of the border attachments.

3. The impression tray has been shortened sufficiently to eliminate its interference with the border tissues during extremes of movement.

4. The impression material used provides sufficient time for adequate border molding under optimum conditions.

5. The lower impression tray is stabilized by an external weight of approximately 175 Gm., which is located directly beneath a bilateral bearing point applied at the anteroposterior center of the tray on each side. The weight and the viscosity of the impression material being constant, a properly trimmed tray assures constant results with a minimum of artificial influences in the establishing of the denture borders.

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EAT, DRINK, SWEAR, QUARREL—AND BE GAY, TOOTHFULLY

By a Wall Street Journal Staff Reporter

The Principles of Ethics of the American Dental Association forbid dentists to advertise but this was not always so. In 1749, an enterprising gentleman named Sieur Roquet who lately had arrived in Boston from Paris placed an ad in the July 3 issue of the Boston Independent Advertiser, which read in part:

"The said Sieur Roquet sells, wholesale or retail, all sorts of legs, arms, eyes, noses, or teeth, made in the genteelest manner, and as now worn by persons of rank in France . . . He also cures effectively the most stinking breaths, by drawing out and eradicating all decayed teeth and stumps, and burning the gums to the jaw bone, without the least pain or confinement; and putting in their stead, an intire sett of right African ivory teeth, set in rose-coloured enamel, so nicely fitted to the jaws that people of the first fashion may eat, drink, swear, talk scandal, quarrel and show their teeth, without the least indecency, inconvenience, or hesitation whatever."

(Reprinted from *The Wall Street Journal* Oct. 2, 1957, by courtesy of the editor of *The Wall Street Journal.*)

REMOVABLE PARTIAL DENTURES

THE REMOVABLE PARTIAL DENTURE IN THE GENERAL PRACTICE OF TOMORROW

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WILL THE PROBABLE *need* for the removable partial denture be inclined to increase or decrease in the next decade? Is the *demand* for this service to advance or decline proportionally with the future need? Must the dentist who engages in general practice be prepared to devote a greater percentage of his appointment time to this type of restorative practice? These are questions of vital interest to the general practitioner of dentistry who wants to be prepared to meet the period of unavoidable pressure ahead, when the demand for dental service will almost certainly exceed the available supply.

There is much to indicate that, in the next twenty-five years, both the need and the demand for removable dental prosthesis will advance sharply. In this period, we may expect no decline in the incidence of the partially edentulous condition as a result of the fluoridation of the public water supply now being utilized at such a rapidly increasing rate. Notwithstanding the mounting evidence of the effectiveness of sodium fluoride in caries control, there must be a lapse of years in which a generation of more immune persons may reach adulthood before a noticeable reduction in prosthetic need can be expected. Meanwhile, however, of those teeth which do develop caries, fewer will be lost because of pulp degeneration than previously. In the first place, on irrefutable evidence, the pulpless tooth is no longer to be regarded as an untreatable health menace[1] which must be eradicated by extraction. More than this, the increasingly effective therapy and technique employed in endodontics today[2] make for an entirely new evaluation of the pulpless tooth situation. Strategically important teeth are being saved today, keeping the patient in the partially edentulous category rather than allowing him to become a candidate for complete dentures.

In a similar way, we find periodontics, as practiced today, being responsible for the saving of the teeth of numerous patients who yesterday would have been made edentulous without hesitation. The alert general practitioner is enthusiastically

Read before the Midwinter meeting of the Chicago Dental Society, Feb. 4, 1957.
Received for publication July 25, 1957.
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applying the principles of modern periodontics with remarkable success. Although many of the periodontally involved teeth will be saved, the condition of some will have gone beyond the treatable stage before therapy was begun. These patients will add to the ranks of the partially edentulous. Of this number, many will have had some teeth which had been seriously damaged by the destruction of much supporting alveolar bone, leaving the teeth weakened and excessively mobile. Here, another phase of modern dentistry can be called into use to render such injured teeth capable of assuming the additional work load of abutment service. By rigid splinting of two or more such weakened teeth, the functional stress load can be distributed so effectively that they may be expected to become firm and healthy in spite of the new abutment work load added.[3] The use of the elastic impression materials for registering multiple cavity preparations has made this splinting procedure accurate and more rapidly accomplished.

To these influences, one other should be listed as having a marked effect in the trend toward an increase in the number of partially edentulous patients. Today, dentists are aware that it is futile to expect satisfactory results from periodontal therapy while tooth movement is allowed to continue unchecked. Once the dental arch is broken by the extraction of some teeth, a progressive deterioration of teeth and supporting structures is almost certain to follow, unless suitable prosthetic measures are taken at once to prevent tipping, rotating, extruding, separating, etc., of the teeth which remain. At long last, the public and the dental profession are coming to appreciate that fixed and removable prosthesis has a value as a *preventive* measure quite as important as that of restoring dental functions. For these and other reasons, the removable partial denture will be *increasingly needed and requested* for at least another twenty-five years. Let us now examine some of the problems of these restorations.

APPLIANCE SUPPORT

The removable dental prosthesis which replaces some missing teeth must belong to one or the other of two types: (1) it derives *support entirely from remaining teeth* (Fig. 1), and (2) it depends upon a *composite support, some of which comes from teeth, but most of which is from structures subjacent to the appliance base* (Fig. 2).

These important dental appliances vary in several respects because of this fundamental difference in the manner in which they receive support. Actually, the chief similarity of the two types is that both are removable.

TOOTH SUPPORT

Where an appliance is tooth-supported (Figs. 3,*A* and *B*), according to Weinmann and Sicher,[4] "The masticatory pressure exerted upon the teeth is transmitted as traction to the alveolar bone proper (lamina dura) via the principal fibers of the periodontal membrane." We may conceive of this support as being accomplished via suspension with the occlusal load being carried in a sling of fibers.

As long as the force load is not excessive and is directed parallel to the long axis of the abutment root, this type of support is one that is quite readily tolerated

physiologically. This suspensory support is characteristic of both fixed (Fig. 3, *B*) or removable tooth-borne (bridge) appliances (Fig. 1).

PERIODONTAL IMPINGEMENT

Wherever the force load is applied to the single-rooted tooth in a lateral direction, the tensile or stretching stress on the periodontal fibers becomes a com-

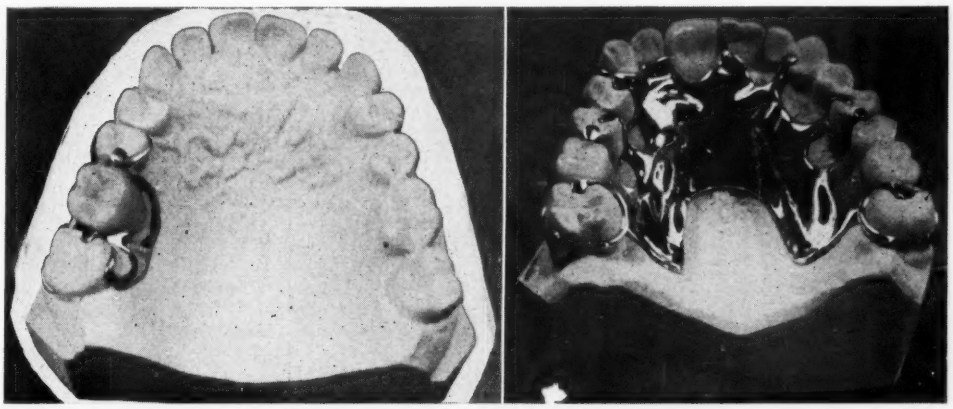


Fig. 1.—Examples of removable restorations replacing missing teeth. Both are clasp-retained and have occlusal rests making them completely tooth-borne. *Left,* The unilateral type which replaces the maxillary right first molar has served comfortably for over 10 years. Both abutments are quite firm. *Right,* The prosthesis is bilateral and, when it was placed, the abutment teeth were quite mobile. After cross-arch splinting was furnished by this appliance, the teeth became much less mobile in spite of the added work load which they were bearing as abutments.

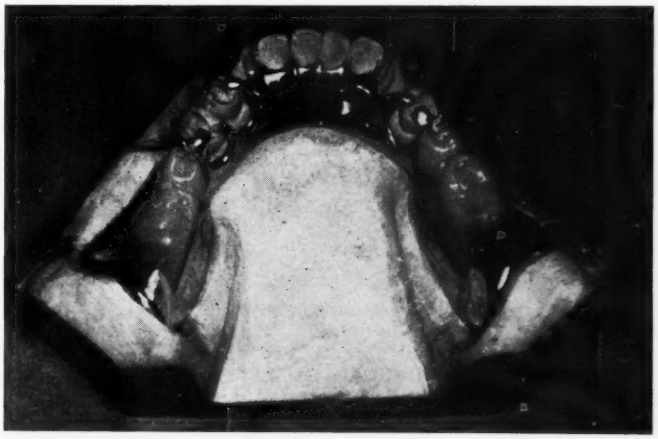
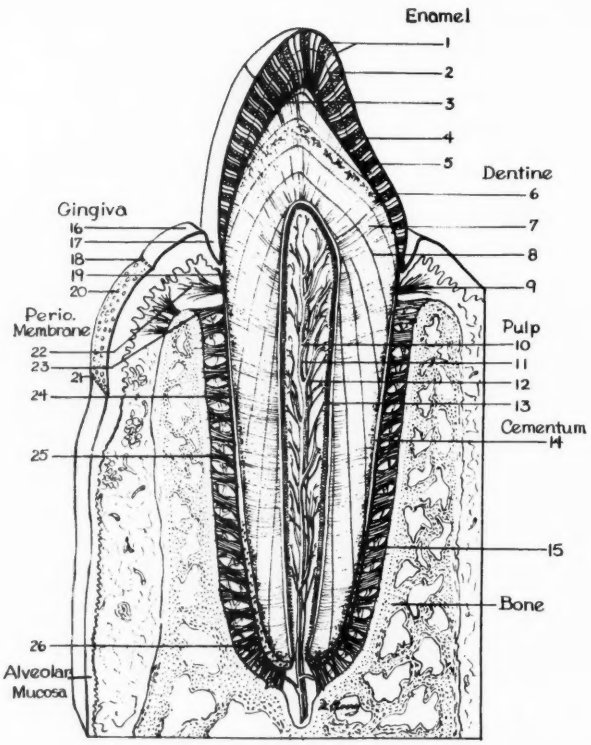
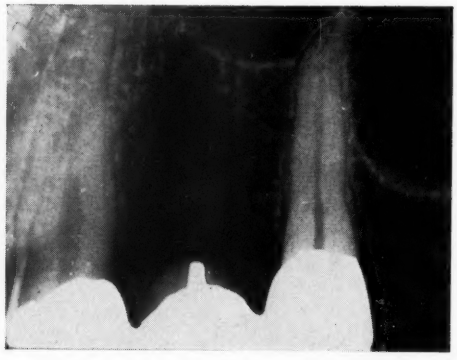


Fig. 2.—A typical removable tissue-tooth supported prosthesis. It is clasp-retained and, since occlusal rests make contact on the abutments, the appliance is partially tooth-borne. The major support, however, comes from the foundation structures upon which the extension (free-end) base is supported.



A.



B.

Fig. 3.—*A*, The arrangement of the principal fibers of the periodontal membrane, which supports by suspension the functional load coming upon a tooth, is shown in Avery's[5] "Diagram of a tooth in situ. Relationship of enamel, dentin, pulp, cementum, periodontal membrane, bone, and gingiva illustrated. Enamel: 1. Schreger bands, 2. incremental lines, 3. lamella, 4. spindles, 5. tufts. Dentin: 6. interglobular spaces, 7. dentinal tubule, 8. incremental line, 9. granular layer. Pulp: 10. veins, 11. arteries, 12. nerves, 13. odontoblasts. Cementum: 14. acellular, 15. cellular. Gingiva: 16. free gingiva, 17. gingival sulcus, 18. free gingival groove, 19. epithelial attachment, 20. attached gingiva, 21. mucogingival junction. Periodontal membrane: 22. free gingival fibers, 23. alveolar crest fibers, 24. horizontal fibers, 25. oblique fibers, 26. apical fibers." (Courtesy of R. W. Bunting, Oral Hygiene, Philadelphia, 1957, Lea & Febiger.)

B, The periodontal support of a fixed prosthesis.

pressive stress in certain areas (Fig. 4, *right*). Of this relation, Tylman[6] says, "When the force is applied from the buccal, it is observed that buccal region of the marginal area *A* is in tension; while on the lingual surface *B*, opposite to the buccal area, the periodontal fibers are under compression. Similarly, it will be observed that from the fulcrum apically the fibers on the buccal surface are compressed *(C)*, while those on the lingual are tensed *(D)*."[6] He adds, "It is well to

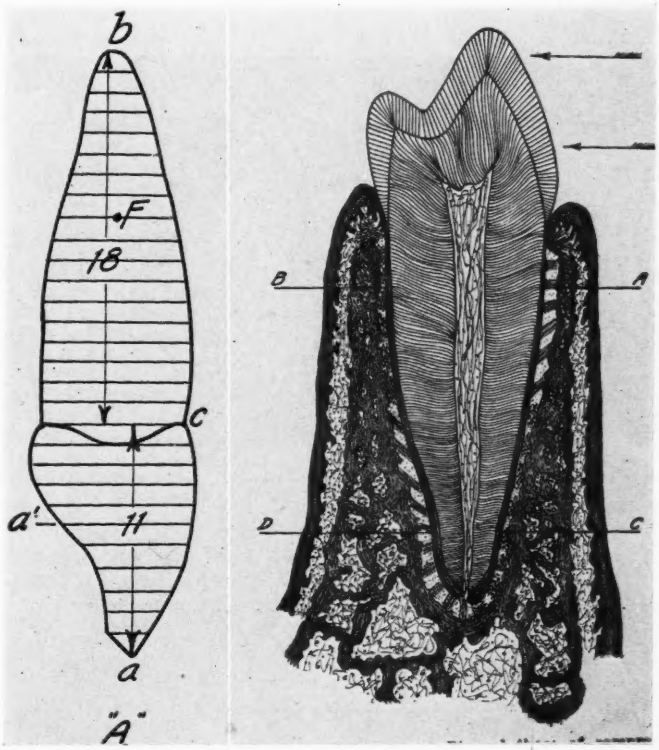


Fig. 4.—*Right*, Areas of tension *(A* and *D)* and those of compression *(B* and *C)* in the periodontal membrane when force is applied from the buccal direction. (After Tylman, Stanley D.: Crown and Bridge Prosthesis, St. Louis, 1940, The C. V. Mosby Co., p. 159.) *Left*, Tylman[6] uses this illustration to indicate the rotation point *(F)* when a tooth is tipped in its alveolus: *aF*, the power arm; *bF*, the resistance arm of the resulting lever.

remember that while the fulcrum of a tooth is in the apical portion of the root (Fig. 4, *left, F*), it is located nearer the middle part than the apex of the root."

Attention is called to a very important point in regard to the tilting movement of a tooth. The fulcrum of rotation is apical, but near to the center of the single tooth root. However, this refers to the *segment* of the root which is supported by bone. Thus, if the level of the bone *(C)* in Fig. 4 *(left)* is lowered by resorptive loss, the fulcrum *(F)* would also lower, and the power arm *(aF)* would be longer with the resistance arm *(bF)* proportionally shorter. This explains why the induced stress is so much magnified when the power arm of the tooth lever has

been made longer by resorption of the cervical level of alveolar bone. Regarding the influence of increased pressure on bone, Weinmann and Sicher[8] make this further observation, "Wherever pressure, whether continuous or intermittent, interferes with the blood supply or blood drainage of bone tissue, osteoclastic resorption of bone results." This possible effect of lateral forces upon the supporting tissues of a single rooted tooth places a significant emphasis on the urgency of avoiding tooth migration by early replacement and of attaining completely balanced occlusion in the teeth supplied to lessen such tilting forces.[7]

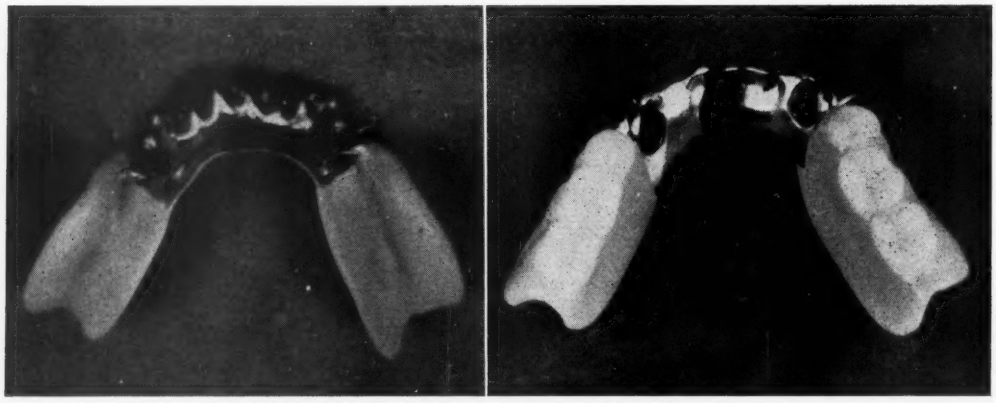


Fig. 5.—A typical extension base mandibular partial denture. It is a Class I (Kennedy) to the first bicuspid abutments—the type of partial denture most frequently encountered at present. The maximum area of supporting structures has been covered by the resin base. It is clasp-retained, with the retentive arms made of high-fusing, 18-gauge round, wrought gold-platinum-paladium alloy. This type of retentive clasp provides a stress-breaking action to lessen the stress which would cause abutment tilting because of movement of the base.

COMPOSITE SUPPORT

If a prosthetic base gets major support from subjacent structures, the transfer of functional loads to the supporting bone is by vertical impact, rather than by tensile suspension. For this reason, in a prosthesis of the extension-base type (Fig. 5), the problem of its support becomes much more complicated and has, also, a greater element of hazard.

COMPARISON OF INDUCED TENSILE AND IMPACT STRESSES

An interesting explanation may be made of why the ridge-borne prosthetic base may be more inclined to inflict trauma as compared to one which is completely tooth-borne. Glickman[9] has said, "The innervation of the periodontal membrane provides a keen proprioceptive sense which localizes external stimuli to the individual tooth." By this mechanism, an involuntary control is placed upon the amount of biting forces developed. Referring to such control, Tylman[10] has stated, ". . . it is the exception rather than the rule, for a patient to bite regularly on any one tooth in excess of 100 pounds. This is so not because the muscles of mastication are incapable of maximum effort, but because the periodontal membrane becomes

painful beyond a certain degree of stress. Teeth endure with difficulty pressure greater than that for which they are suited, the membrane acting as a safety gauge." As a result of proprioceptive innervation, there is an *involuntary* reduction of the biting force exerted even *before* consciousness is registered of any discomfort in the periodontal tissues. Thus, the structures supporting the tooth-borne prosthesis are protected from overload by a very effective mechanism which operates involuntarily.

Not so with the extension-base partial denture, however. When work loads are passed by such appliances to the sub-basal structures, there is greater danger of their injury. In the first place, the tissues covering the supporting ridge are thought to have much less proprioceptive innervation than the highly specialized periodontal membrane. Hence, excessive biting force may not be sensed soon enough to avoid trauma to the tissue receiving the impact. Second, the force load is received as a compressive impact which may readily occlude the vessel walls,

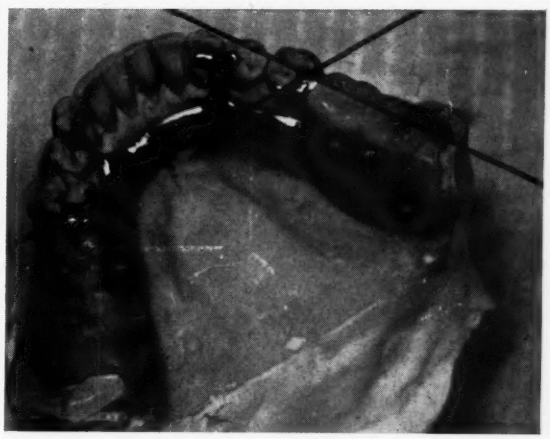


Fig. 6.—The fulcra of possible movements of an extension base partial denture. The base may move vertically toward or away from the ridge; the free-end of the base may move laterally, or it may rotate over the ridge crest.

resulting in ischemia. Third, if the impact has been excessive, there may be actual bruising or cutting of the mucosal surface. Finally, there may be added still another hazard because, if there has been resorptive change of the foundation structures, the base of the prosthesis will move toward the ridge surface. In Fig. 6, the possible movements of an extension-base appliance are depicted as developing around certain fulcra. When the base moves vertically toward or away from the ridge, there is rotation around that fulcrum which extends from the right to the left abutments. Actually, this movement occurs where the occlusal rest contacts the marginal ridge of each abutment which borders the edentulous area. A lateral movement of the free-end base may also occur, in a horizontal plane, with the appliance tending to pivot at the abutment tooth. There is one other movement. It is rotational around a fulcrum which parallels the crest of the ridge and passes through the occlusal rest (Fig. 6).

Movement of the extension base toward the ridge results from loss of subbasal structures following resorptive change or because of lack of sufficient stability to support the applied load. As the resulting induced leverage tends to tilt the abutment tooth in its alveolus, areas of the periodontal membrane will be subjected to compressive, injurious stress (Fig. 4).

If the mechanism of supporting each type of removable appliance is understood and the nature of the stresses being induced by each is comprehended, a big step has been taken toward bringing the resulting tissue loads within the limits of tolerance. To alter clinical procedure or appliance design in order to alleviate an unsatisfactory result, one first must know something of the cause of the trouble.

Fig. 7.—A roentgenogram of an edentulous condition typically suited to a unilateral design type of prosthesis—a short span, with well-formed abutment roots supported by excellent bone. A clasp-retained, removable bridge (See Fig. 1, *left*) had been worn for 12 years when this roentgenogram was made. The patient was past 50 years of age when the restoration was placed.

WHEN A TOOTH-BORNE PROSTHESIS SHOULD BE BILATERAL IN DESIGN

Reference has been made to the hazard of tilting forces on abutment teeth. It also would seem desirable to suggest a control for this situation. Why and when should a tooth-borne restoration be extended across the dental arch, rather than to use a fixed or removable *unilateral* appliance? Tylman[11] says regarding lateral stresses, "What frequently has been attributed to overload rightfully should have been ascribed to the ill effect of leverage. Even excessive vertical forces occasionally exerted on a tooth do not cause permanent injury; rather, it is the unnatural buccolingual or torsional movements that cause the harm." When conditions are such as to result in this type of lateral tipping, it is very important that the situation be recognized and that a unilateral appliance be avoided. The following analysis of the factors upon which this decision should be based obviously is oversimplified because of space limitation.

1. Use a *unilateral* fixed or removable prosthesis (Fig. 7) when: (1) the edentulous span is short; (2) the cervical level of the abutment supporting bone is physiologically normal; (3) the abutment root length and form is average or better; (4) the occlusal work loads are not excessively heavy and are directed parallel to the abutment root axis.

2. Use a *bilateral* removable prosthesis (Fig. 1, *right*) when: (1) the edentulous span is long (more than two missing posterior teeth); (2) the alveolar bone support is inadequate (Fig. 8) with a long extraosseous segment in relation to a

shortened intraosseous sector of abutment root; (3) the abutment root length and form is poor; (4) the occlusal stress load is heavy or is so directed as to produce a lateral tilting of the abutment.

Under various combinations of the above adverse conditions, a unilateral fixed or removable partial denture would probably show signs of early failure. It is not so much the *amount* of the functional load which is responsible for such default as it is the *direction* in which the increased stress is applied.

BILATERAL RATHER THAN UNILATERAL DESIGN

The basic reason, then, for deciding to utilize a bilateral prosthesis is not that it is removable, but rather that in this design the principles of cross-arch splinting and counterleverage can be so effectively employed as to nullify any adverse tilting force. If a rigid connector is employed to extend to a remote abutment on the opposite side of the arch, potent counterleverage is developed to stabilize the weakened abutments. The length of this extended counterlever is then many times that of the work lever which produces the tissue impingement. This work lever would

Fig. 8.—A partially edentulous upper arch in which *unilateral restorations, fixed or removable, are contraindicated.* The replacement of these teeth was bilaterally executed because the cervical bone loss around the abutment teeth had created a situation of unfavorable leverage. This further magnifies the work load which must be borne by a greatly reduced area of alveolar wall support. Cross-arch splinting was needed in this situation to restrict abutment tilting. It was supplied by a bilateral design, such as is shown in Fig. 1, *right.* That bilateral tooth-borne prosthesis has been worn several years, the abutment teeth becoming more firm than they were when the appliance was placed.

extend from the point of abutment tooth rotation to its occlusal surface. The point of tooth rotation is near the mid-point between the cervical bone level and the tooth apex. Thus, a very decided lever advantage will rest with the cross-arch extension, and abutment tilting will be effectively counteracted. This is the reason that mobile teeth will become firm after a bilateral removable appliance has been placed, a result which is seen even when the appliance actually induces much more work. Before rehabilitation the same teeth may have been mobile, although they were then doing only the limited work which occurred on their own surfaces. There is no more effective way to overcome leverage than by using a longer counter lever.

IMPRESSION REQUISITES FOR TOOTH-BORNE REMOVABLE PROSTHESIS

When the abutments only are to furnish support, it follows that the base will need to have an accurate adaptation to the anatomic form of the teeth and to the rest form of the ridge area. No attempt is made to extend the base beyond a convenient coverage, since it serves only to carry the supplied teeth and not to achieve support for functional loads. For this type of prosthesis, one of the hydocolloid materials gives an adequate impression[12] of extreme accuracy.

A rubber-base impression material, mixed like dental cement, also gives an excellent impression of anatomic form. It has shown two extremely practical advantages. (1) There is insignificant volume change of this material even when it is exposed directly to air, and (2) the material has no unfavorable reaction on contact with gypsum products as may be seen in the hydrocolloids when, through syneresis,[13] they may give off an exudate which retards the setting of dental stone. My experience in the clinical usage of these rubber-base compounds has been very encouraging. The principal deterrents to their usage are the need for making a special resin tray for each impression[14] and the present high cost of the product. Neither of these objections is too serious, however, if the advantages are as outstanding as they now seem to be.

SOME ESSENTIAL REQUISITES OF THE EXTENSION-PARTIAL DENTURE

The hazards of the extension-type prosthesis have been noted, and reasons for the problems peculiar to these appliances have been explained. Let us now examine a few measures which may be taken to avoid some of the unfavorable results.

AVOID RESORPTION OF FOUNDATION STRUCTURES

It has been shown that much of the difficulty of resorption stems from the loss of stability of the base, allowing the appliance to have excess movement. How can this change be minimized? A partial listing of things that may be done would include the following: In cases of extremely long periods of ridge disuse: (1) recondition the foundation-area structures before they are to be used to support a work load; (2) assure a proper tissue-base relationship during periods of rest and when occlusal forces are being applied; (3) extend the base to provide maximum mandibular and adequate maxillary coverage; (4) reduce the occlusal table area and maintain a balanced occlusal relationship; and (5) use metal for the construction of the base whenever possible.

RECONDITIONING THE ALVEOLAR BONE

One of the most difficult situations with which the prosthodontist must deal is that existing when disuse atrophy (osteoporosis) has occurred in the edentulous area. Frequently, the missing teeth may have been extracted many years before their prosthetic replacement is accomplished. Bone is maintained only in response to the stimulation associated with its functional use.[15,16] Of this, Weinmann and Sicher[16] say, "If the loss of teeth is extensive or if the teeth bordering the edentulous area have lost their function, for instance, through the elimination of their antagonists, the osteoporosis is much more severe and the loss of bone substance

at the alveolar ridge is much greater."[16] One of the most common errors in prosthodontics is to assume that, because the bone is being maintained normally in the area of remaining teeth which have received greater than normal function, the edentulous ridge in the same mouth also will furnish stable support immediately (Fig. 9).

Frequently, the replacement of teeth is done in a manner to restore a nearly normal functional load to such edentulous areas, only to have a rapid resorptive change occur beneath the denture base. I make a plea for the preconditioning of

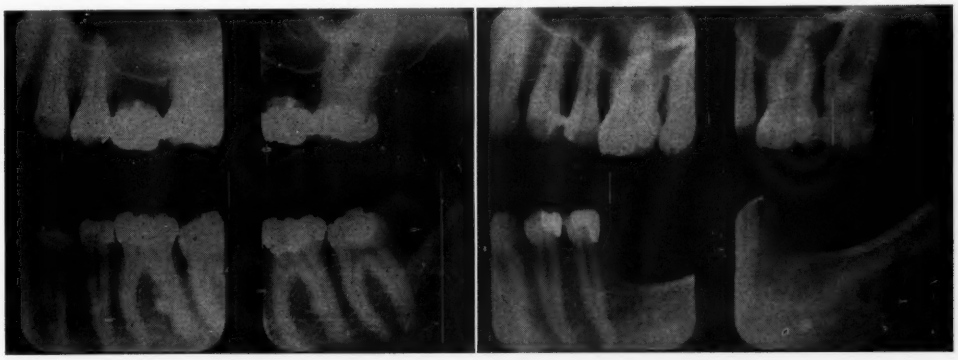


Fig. 9.—These roentgenograms show evidence of very fine bone maintenance in areas where there has been more than average functional load: (1) The maxillary abutment teeth have had the extra work of supporting the fixed prosthesis for many years. (2) The teeth adjacent to the edentulous area have had to assume some of the biting forces formerly shared with the teeth which have been missing for a very long time. Yet, in the mandibular edentulous sector of this same mouth, there is evidence of much loss of bone as a result of disuse. (From Applegate, Oliver C.: Conditions Which May Influence the Choice of Partial or Complete Denture Service, J. PROS. DEN. 7:182, 1957.)

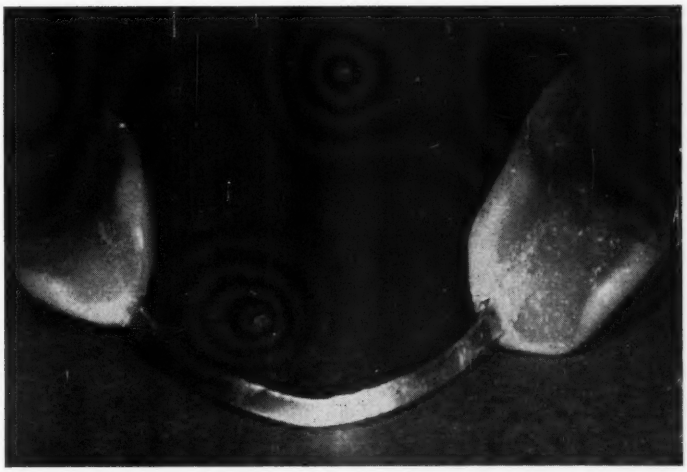


Fig. 10.—One type of *exercise* prosthesis. The resin bases have been constructed on a cast made from a correctable impression of the foundation area. The borders are extended to moving peripheral tissues, and the basal surface is supported throughout when finger pressure is applied. Exercise should be given daily by finger contact simultaneously on each base, or by biting on the fingers if there are opposing teeth.

the residual alveolar ridge, where there has been long disuse, before the normal stress load is restored. This can be done by one of the following procedures:

1. Supply a temporary exercise prosthesis for use over a period of a few months (Fig. 10).

2. Construct the appliance with the base adapted to functional form and extended to maximum area, but do not replace the teeth until later (Fig. 11).

In addition, have the patient exercise the ridge area with finger massage prior to the prosthetic service, while restorative and other mouth preparation is being done. Be certain, also, that the diet and vitamin intake is proper and that the physical condition of the patient is such as to assure the best possible metabolic function.

Of the exercise methods suggested above, either or both may be used. If there are extensive restorative changes to be made in the remaining teeth, which are likely to require many weeks, it would be of value to supply a temporary exercise prosthesis (Fig. 10).

To be of value, the ridge surfaces of the exercise bases should not only be maximum in area, but they should be related to the basal structures exactly as the bases of the finished partial denture will be (Fig. 10). The daily two or three exercise periods of intermittent biting pressure will then direct stimuli through the base into the substructures in the same manner that work stimuli will later be induced by tooth surface contacts. Under this method of bone reconditioning, the edentulous ridge may be expected to undergo a process of reorganization which will prepare it to accept a reasonable occlusal load, at a later time, with much less resorptive change. Such an exercise prosthesis may be used with an occlusal rim of soft resin which has been adjusted to balanced occlusal relation with the opposing teeth. However, it is preferable to avoid the possibility of continued application of occlusal force, such as might occur in periods of bruxism if an occlusal contact is provided. Biting on the fingernail also provides a control of the force load which is not unlike the proprioceptive mechanism of the periodontal membrane. It hurts to bite too hard on the fingernail, so the pressure applied will be limited.

A second method of supplying this type of reconditioning through exercise of the sub-basal structures is more adaptable to a situation where no great amount of mouth preparation is required. Here, the procedure is to construct the appliance framework as usual, using it to carry and orient properly the correctable impression of the foundation area. The base is then constructed to a maximum area and to the supporting form (Fig. 11).

The reconditioning of an edentulous area, where disuse atrophy may have resulted in retrogressive changes, offers a way of avoiding the unnecessary loss of ridge structures that follows the application of initial work load which exceeds the supporting ability of the bone because it is not accustomed to work.

CONCLUSIONS

There are convincing indications that removable partial denture prosthesis will compose a very considerable part of the dental service rendered in the general practice of tomorrow. The fixed tooth-borne restoration will continue to be a most

satisfactory method of tooth replacement where it is indicated. The interabutment splinting accomplished by this appliance is a principal reason for its fine service record. Another important explanation is that a tooth-borne replacement transfers the work load to the foundation bone through the principal periodontal fibers by traction. In the future, there will be greater effort made, therefore, to retain posterior abutment support so that the prosthesis used may be *tooth-supported*. Frequently, however, there will have been previous loss of alveolar bone around the prospective abutment, resulting in a weak abutment tooth. This situation indicates the use of the *bilateral* tooth-borne removable prosthesis. It achieves the desirable cross-arch splinting and succeeds where unilateral fixed partial dentures would fail. Where possible, the use of multiple abutments will continue to be the procedure of choice when weakened teeth must be used. Rigid splinting has been removed from the list of dentally unpardonable operative sins. Its use will continue to be the means of saving many teeth weakened by periodontal damage and loss of alveolar support.

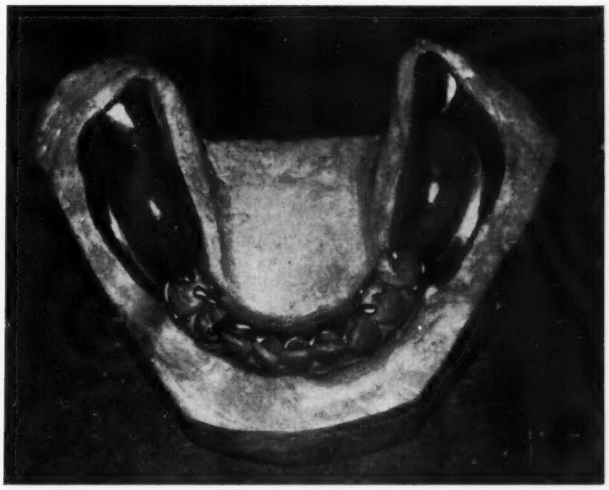


Fig. 11.—An *exercise* prosthesis which utilizes the framework and bases of the finished partial denture. Narrow occlusion rims of soft resin may or may not be added. In either event, the appliance is used to supply work-stimulation to the foundation area by biting on fingers placed simultaneously on the right and left sides. Teeth will be added to the appliance three or more months later when the ridge structures are conditioned to work loads.

But when no posterior abutment remains, the transfer of the occlusal loads to foundation bone must be made by direct impact of the appliance base to the covering of the supporting ridge. Here, the proprioceptive mechanism, which protects the tooth from excessive biting force, is almost absent. The result is frequent damage to the mucosal pad and then to the underlying bone. The use of a *conditioning* or *exercise* prosthesis has been suggested to recondition the alveolar process by controlled work loads which will stimulate bone reorganization but which will not exceed its tolerance. With suitable exercise, the teeth can be added to the

base in a few months, and a reasonable functional load will be tolerated without resorptive change. Edentulous areas which have undergone disuse atrophy can, in this way, be returned to a condition so that they will provide stable support for the partial denture extension base.

It is urged that the general practitioner be prepared to meet an increasing demand for removable partial denture service. He should become thoroughly informed regarding the principles of design of both the tooth-borne and the extension-base removable types of partial dentures. By the careful survey of the accurate study casts, he will be able to determine the tooth alterations needed to eliminate interference to appliance insertion and removal and to secure suitable clasp retention. He should prepare the mouth as the survey of the study casts has indicated and then prescribe the exact design which he wishes the dental laboratory technician to produce. The results of carefully planned oral rehabilitation, utilizing the removable partial denture, will then be a source of pride in the general practice of dentistry. No service will give an operator more genuine pleasure.

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THE PROBLEM OF THE LOWER FREE-END REMOVABLE PARTIAL DENTURE

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THE REPLACEMENT OF NATURAL posterior teeth which have been lost is undertaken to restore function, to prevent overeruption or drift of opposing teeth, to prevent movement of the teeth adjacent to the denture base, and to prevent loss of vertical dimension.

For many years, prosthetic restorations have been designed to fulfill these requirements satisfactorily from a purely mechanical point of view, only to fail through a lack of appreciation of the biologic factors involved.

More recently, it has been realized that maintenance of the health of remaining teeth and their supporting tissues is of paramount importance, and this has been reflected in the type of restorations that have evolved.

What are the adverse changes which may occur through failure to restore the dentition, and what are those induced by partial dentures of unsatisfactory design? An attempt will be made to answer these questions, the various aspects of denture design in relation to the free-end removable partial denture will be discussed, and a new approach to this type of prosthesis will be suggested.

EFFECTS OF NOT RESTORING THE DENTITION

Temporomandibular Joint Dysfunction.—Failure to replace posterior teeth which have been lost throws an additional load on the remaining anterior teeth, and a continual forward posturing of the mandible may be necessary to enable these teeth to serve a masticatory function.

In the absence of a normal occlusal relationship, overclosure of the vertical dimension of occlusion is frequently seen, and the lower incisor teeth may impinge upon the gingivae of the palate. In either of these circumstances, the condyle will habitually occupy an abnormal position in relation to the other joint structures, and symptoms of varying severity may arise in the temporomandibular joint directly, through the absence of a normal occlusal relationship between posterior teeth.

Overeruption of Unopposed Teeth.—A further consequence of not replacing missing posterior teeth is the overeruption of teeth which cease to have a functional occlusion. This overeruption may be so gross that the occlusal surface of the tooth concerned makes contact with the mucosa of the opposing jaw and completely obliterates the maxillomandibular space or the tooth may be raised only slightly

Received for publication Aug. 17, 1957.
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above the occlusal level of the adjacent teeth. Not only may this overeruption give rise to difficulties in providing space for an opposing artificial tooth, but it will impair normal occlusal movements and throw an additional strain upon the natural teeth which come into traumatic occlusion and also upon the temporomandibular articulation.

Atrophy of Alveolar Bone.—It has been postulated that, following the extraction of teeth, the alveolar bone, having lost its primary function, will resorb and that the resorption may be retarded if the surface of the bone is utilized to assist in bearing some of the masticatory load through a denture base. Failure to restore the missing teeth by means of a denture may, therefore, be followed by "disuse atrophy."

TISSUE DAMAGE ASSOCIATED WITH THE WEARING OF PARTIAL DENTURES

Caries.—Bacterial activity is dependent upon plaque formation, and this occurs commonly in sites protected from the normal cleansing action of the tongue and cheeks. Caries susceptibility is increased when stagnation of food debris and organisms occurs at the tooth surface. For this reason, the crowns of the remaining teeth should be left uncovered as much as possible, and where the denture contacts the teeth, it should fit as closely as possible.

Gingival Inflammation and Hyperplasia.—Among the local factors responsible for gingival damage, stagnation features prominently. Where the shape and inclination of the teeth are such that undercut areas exist in relation to the path of insertion of a removable partial denture, stagnation will occur between the teeth and the denture when a lingual plate type of construction is used. Gingival margins which are covered in this manner may become inflamed, and if environmental conditions remain unchanged, the free gingival tissue becomes hyperplastic. The hyperplastic tissue may grow until it obliterates the space existing between the denture and the teeth.

Overstress of the Periodontal Membrane.—That a healthy periodontal membrane is capable of successfully withstanding more than its fair share of the masticatory load is the conclusion to be drawn from successful fixed partial denture restorations. That its ability to withstand additional loads is limited is also evident from the loosening of remaining teeth subject to overstress. The ability of a tooth to withstand loads is related not only to the magnitude of the force applied but also to the direction of that force. Vertical forces applied down the long axis of a tooth are better withstood than torsional loads or those applied in a different direction than parallel to the long axis.

Gum Stripping.—Vertical movement of a denture due to displacement of the underlying soft tissues or resorption of the alveolar bone will be accompanied by injury to the free gingivae if the denture base material is in contact with it. The horizontal periodontal fibers become detached, and the cementum is exposed. The inflammation which accompanies this injury is responsible for the further resorption of the adjacent bone.

Alveolar Resorption.—The alveolar ridge will resorb at a variable rate, and this loss may be retarded if the bone is allocated a functional role in supporting a

denture base. Thus, while alveolar bone will withstand the forces of mastication transmitted as traction through the periodontal fibers, it seems that it is able to withstand compressive loads transmitted to it by a denture base to a lesser degree.

Apparently, there is an optimal load which the residual alveolar ridge will withstand beyond which the pressure applied serves to stimulate bone resorption. In order to minimize the load acting upon a unit area, tissue-borne denture bases must cover the maximum surface possible.

In nonstress-broken free-end removable partial dentures, it is common practice to support the denture by means of occlusal rests on the natural teeth. Under these circumstances, vertical movement of the denture base toward the tissue, which may accompany displacement of the covering mucosa or resorption of the underlying bone, results in a rotation of the denture about an axis joining the occlusal rests on the abutment teeth and a concentration of the occlusal load on the residual alveolar bone at the distal end of the denture base. The leverlike action of the denture base as it moves tissueward tends also to induce a torsional strain on the teeth

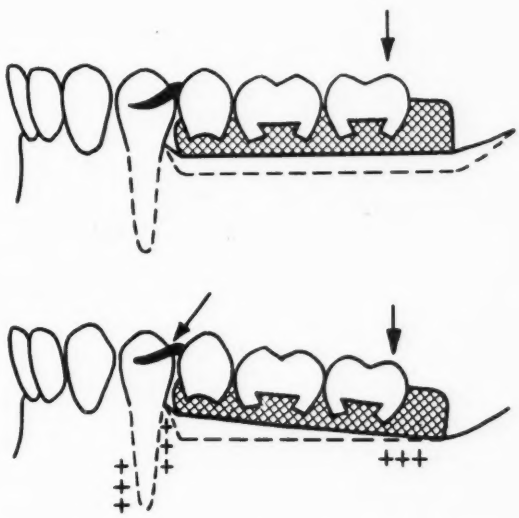

Fig. 1.—Stress concentration occurs primarily on the abutment tooth and at the distal end of the denture base when the conventional free-end removable partial denture is used.

adjacent to the denture base if these teeth are rigidly clasped. The stress concentration occurring on the abutment tooth and the supporting foundation is illustrated in Fig. 1. The excessive loading of the residual bone beneath the distal end of the denture base induces rapid bone resorption which is accompanied by further movement of the denture tissueward and a further progression of these deleterious effects.

While the foregoing facts reflect a true picture of what is so frequently seen in clinical practice, the whole subject of bone resorption is one about which little is really known. The ability of the residual alveolar bone to withstand forces applied

to it must be related to its structure. When periodontal infection existed prior to the extraction of the teeth or in endocrine disturbances associated with the menopause, a far more rapid bone loss seems to occur. Bone loss is not necessarily confined to what is considered to be the residual *alveolar* bone. Periodically, the neurovascular bundle becomes exposed upon the surface of the residual mandibular bone presenting a further embarrassment to prosthetic treatment.

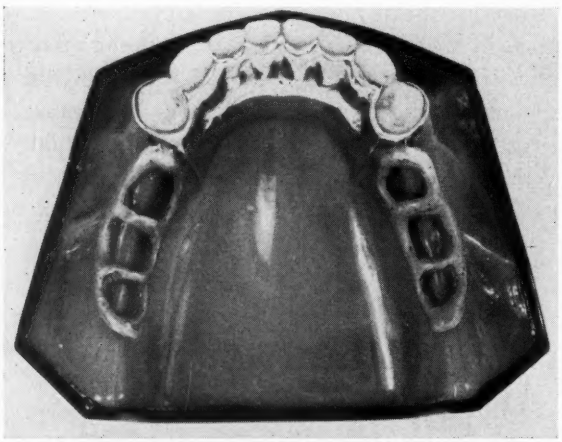

Fig. 2.—A lingual plate is used to supply indirect retention.

DENTURE DESIGN

Although it is desirable to restore missing teeth, the adverse effects of unsatisfactorily designed partial dentures should be avoided. Various aspects of design in relation to the lower free-end removable partial denture will be considered.

Connectors.—In bilateral partial dentures, the two saddles (denture bases) must be joined together. Normally, the dentist has a choice between a plate covering the lingual aspect of the remaining teeth and gums or a bar relieved from the tissues and passing in the lingual or labial sulcus.

The lingual plate type of connector (Fig. 2) is usually well tolerated by the tongue, and the tendency for the distal end of the denture to lift is opposed. Where only incisor and canine teeth remain, the lingual plate is preferred and, if possible, the denture base material should be carried right into the gingival crevice. Where the lower premolar teeth remain, however, they frequently show such a marked lingual inclination that the insertion of a lingual plate results in an area of stagnation between the denture and the teeth and gingivae. In order to avoid such stagnation areas, rigid connectors running in the sulci are employed. These bars are positioned midway between the gingival margin of the remaining teeth and the functional depth of the sulcus, and a prerequisite for their use is an adequate depth of sulcus to accommodate them. The lingual bar connector (Fig. 3) may not be tolerated as well as the lingual plate, but patients usually become accustomed

to it, and it is widely used. The shape of the bar may be varied, but the one most readily tolerated is that having a half pear-shaped cross section.

The labial connector (Fig. 4), which is used only when the gross lingual inclination of the lower teeth is such as to preclude the use of the lingual bar, is usually very well tolerated if it is correctly positioned and relieved from the underlying tissues.

Fig. 3.

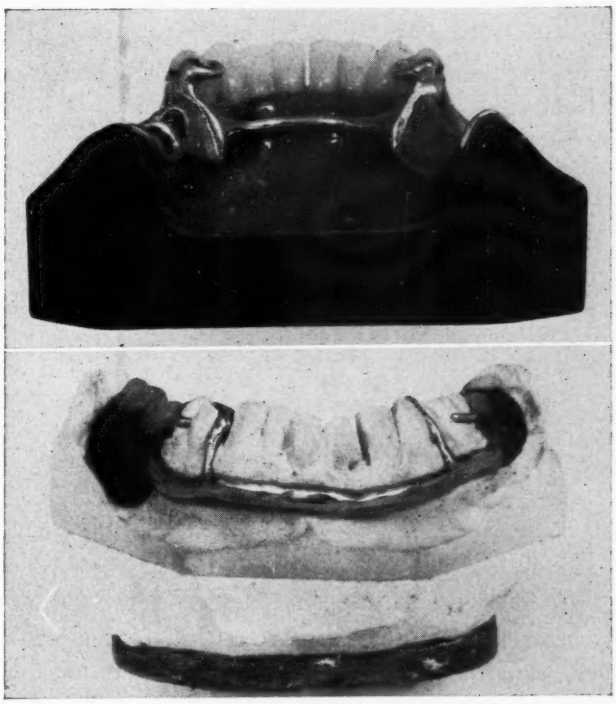

Fig. 4.

Fig. 3.—A lingual bar connector.

Fig. 4.—A labial bar connector is used only when the lingual inclination of the lower teeth is such that the use of the lingual bar is impossible.

Occlusal Rests.—Occlusal rests are provided to prevent tissueward movement of all or part of the denture, to transmit some of the vertical loads applied to the denture bases to the remaining teeth, to protect the gingivae adjacent to the denture base from the effects of food impaction, and occasionally to restore occlusal contact. The shape of incisor and canine teeth is unfavorable for occlusal rests and, although embrasure hooks or incisal overlays are employed sometimes on these teeth, they are unsightly. Usually, it is necessary to insert some form of restoration in these teeth if they are to accept their share of the vertical component of the masticatory load applied to the denture bases. Occlusal rests should be designed to have adequate strength to transmit forces along the long axis of the abutment

tooth upon which they are placed, and they should not interfere with the movements of the opposing teeth. Occlusal rests often are placed on the disto-occlusal surfaces of the two teeth adjacent to the denture bases, and these two rests provide an axis about which rotation of the denture may occur if such movement is unopposed.

Indirect Retainers.—Indirect retainers are portions of a denture which resist the movement of parts of a denture remote from themselves, and they are used in association with free-end denture bases. The distal ends of such a denture may lift and, with clasps and rests placed on the teeth adjacent to the denture base, a rotation occurs about a line joining these teeth. This movement may allow part of the connector uniting the denture bases to contact the mucosa. This lifting may be opposed in various ways. Circumferential clasps may be used which engage distal undercuts, or back action clasps which grasp the tooth mesiodistally may be employed. These two methods are modifications of the direct retainer.

Indirect retainers are extensions of the denture framework which rest on the lingual side of the remaining anterior teeth or upon the occlusal surface of premolars anterior to the last abutment tooth. The number of teeth contacted by these devices may be few or many, but it is preferable that such force as is transmitted by these retainers be shared by the greatest number of teeth possible in order that each individual tooth is under as little stress as possible. Lateral forces applied to the free-end denture base are also effectively opposed by some forms of indirect retainers, and thus the underlying mucosa and bone is protected from the injurious effects of excessive pressure.

Stress Breakers.—The principle of stress-breaking in partial dentures is designed to allow a certain amount of movement of the denture bases, while at the same time the torsional strain, which would otherwise be applied to the remaining teeth, is minimized.

Some stress breakers serve merely to protect the teeth adjacent to the denture bases from injury, while others are intended to protect the residual alveolar bone from the damaging effect of stress concentration to which previous reference has been made.

A number of devices have been employed to achieve this end with varying degrees of success. These include flexible clasps and flexible retainers.

Bar clasps with their arms approaching the tooth from the gingivae have the advantage that, by varying the length of the clasp arms, the resilience of the retainer may be altered. These clasps may also be constructed from a wrought wire which has a modulus of elasticity that is lower than that of its cast equivalent. Many retainers of this type only make point contact with the tooth surface, thus further minimizing the torsional stress which they may apply. The shortcoming of this type of clasp is that it may allow the denture base to be displaced away from the abutment tooth and allow food to pack down upon the proximal gingivae.

When a Kennedy bar (continuous bar) retainer unit is used in association with a lingual bar connector, they have to be joined and the connection may be modified to allow a certain amount of movement of the denture base without adversely affecting the clasped teeth (Fig. 5). Long flexible connectors may be em-

ployed to unite the rigid bar with the retainer unit. Such stress-breaking units tend to be poorly tolerated by the tongue, and tissue proliferation may occur between them because of stagnation which causes inflammation of the underlying mucosa.

COMPOSITE DESIGN

A number of systems have been devised to avoid overstress to the abutment teeth, and these were reviewed by Steiger[1] in 1952.

Many of the solutions propounded necessitated the splinting of the remaining teeth by fixed partial dentures or by the incorporation of internal attachments in the abutment teeth. While such carefully engineered appliances may give excellent results, they can, for economic reasons, only be made available to a very small number of patients.

In attempting to transfer the occlusal stresses to the alveolar bone and abutment teeth in optimal proportions, partial dentures of composite design have been evolved.

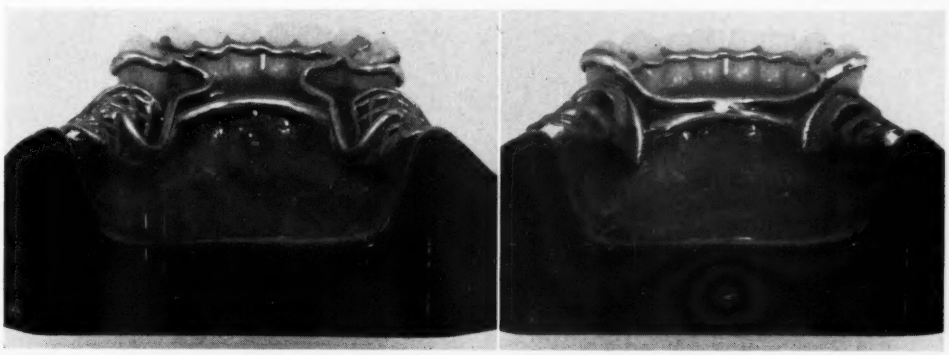

Fig. 5.—Two partial denture frameworks with flexible connectors for stress-breaking.

The Fischer and Frey systems[1] are examples of the hinge type of denture construction in which a degree of movement of the denture base is allowed through the nonrigid connector adjacent to the abutment teeth. This eliminates stress on the abutment tooth, but it does not prevent the greater part of the occlusal load from being transmitted to the bone beneath the distal end of the denture base.

Steiger's own system,[1] the axial rotation joint, is designed to allow movement of the entire denture base in a vertical direction, and this helps to overcome the problem of stress concentration on the residual ridge.

THE FLOATING BASE PARTIAL DENTURE

The examples which have been illustrated (Fig. 5) are of somewhat complex construction, and the laboratory work is time-consuming. An alternative design, which deals satisfactorily with most of the problems of free-end partial dentures and in which the method of construction has been considerably simplified, will be

described. This design consists of a single casting which provides the retainer unit and two separate bases which are supported at each end but which are allowed a degree of independent movement.

TECHNIQUE OF CONSTRUCTION

Stone casts are obtained from hydrocolloid impressions made in special trays. These casts are mounted in an adjustable articulator and surveyed. The design of the retainer unit is planned on the master cast, and undesirable undercuts are eliminated with wax or plaster. A single thickness of modeling wax is adapted over the residual ridge in each of the free-end denture base areas (Fig. 6), and the cast

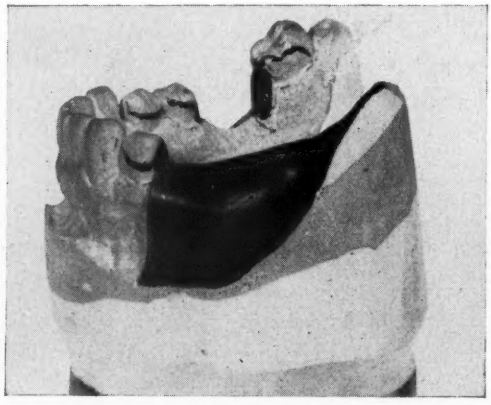

Fig. 6.—Wax is adapted to the master cast prior to duplication.

thus prepared is duplicated in a suitable refractory investment material by means of an agar-agar duplicating gel. After the refractory cast has been hardened by impregnating it with stearine, it is ready for the wax-up of the denture framework. The conventional retainer and connector units are waxed up in the normal manner. The slots by which the denture base is supported are placed in the center of the neutral zone behind the last abutment tooth and immediately behind the position which will be occupied by the last artificial tooth. They are positioned below the plane of occlusion of the teeth.

Two supporting arms are adapted on the refractory cast, one in the buccal sulcus and one in the lingual sulcus. These supporting arms unite, forming a loop, just behind the predetermined position of the last artificial tooth. The lower border of each bar should be at least 3 mm. from the functional depth of the sulcus, and particular care should be taken to allow for the forward thrust of the masseter muscle which will not be recorded under normal methods of impression making. These bars are formed from half round or oval section waxes of approximately 3 mm. depth, the gauge of the wax being varied according to the modulus of elasticity of the metal to be used in the casting. Since the purpose of these bars is to give rigid support to the denture framework, they could be constructed from a chrome-cobalt or nickel chrome alloy.

Slots must now be prepared at each end of the denture base to accommodate the male portion of the coupling which projects from the acrylic resin base.

Where the supporting bars unite, the wax is thickened and oval slots are prepared. At the mesial end, the slot takes the form of a chamber 1.5 mm. deep facing backward, while, at the distal end, the framework is perforated (Figs. 7 and 8). The metal projection from the acrylic resin denture bases is formed by 0.8 mm. stainless steel wire, and the slots prepared in the wax are 1.6 mm. in height and 0.8 mm. in width. The wax pattern is sprued and cast. The casting is finished, fitted to the master cast, and the denture base units are prepared.

A sheet of modeling wax is adapted on the cast to form a base which occupies the space which exists between the supporting bars and the cast.

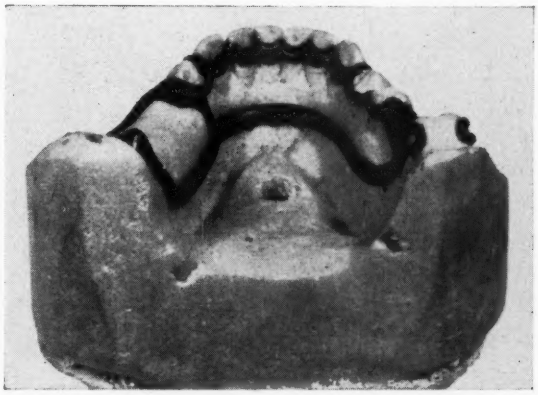

Fig. 7.—The wax pattern for the retainer unit on the refractory cast.

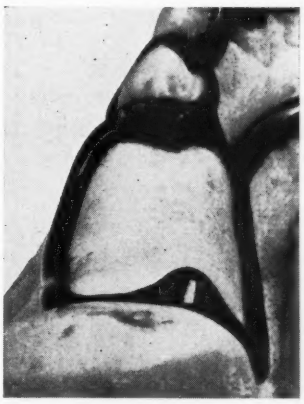

Fig. 8.—The oval slot to form the female part of the coupling is carved in wax.

TECHNIQUE WITH ACRYLIC RESIN TEETH

When acrylic resin teeth are used, the retention can be provided by a stainless steel rod which transfixes the denture base by fitting into the mesial slot in

the denture framework and also passing through the distal loop of the framework. This is accomplished by enclosing that portion of the rod which will pass through the base in a close-fitting stainless steel tube and waxing it into position so that the rod is in contact with the top of the female couplings. Then the teeth and the remainder of the denture base are waxed up. That portion of the pin which projects behind the distal coupling should be oiled and enclosed in a bridge of wax which forms part of the denture base.

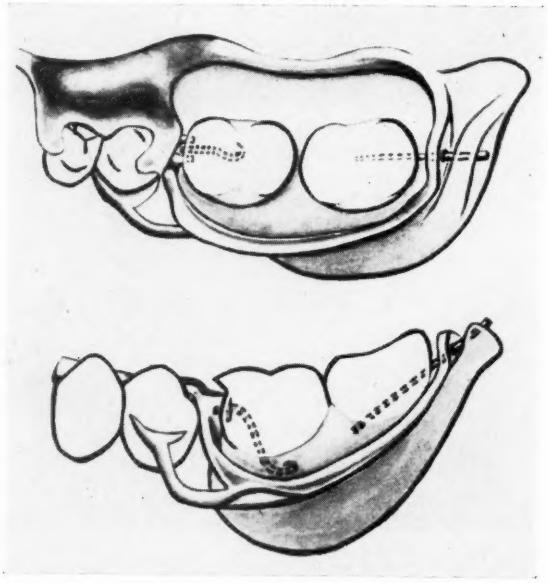

Fig. 9.—The connection between the denture base unit and the retainer unit must allow adequate space for the attachment of teeth. Note the location of the stainless steel lodging wires.

When the try-in is satisfactory, the pin is withdrawn, and the waxed-up denture base is processed. After polishing, the denture base may be put into position in the framework and locked by replacing the pin. In order to fix the denture base permanently in place, the pin is cut so that, when it is pushed into place, its end disappears into the acrylic resin behind the distal attachment. This hole is then filled with autopolymerizing acrylic resin.

TECHNIQUE WITH PORCELAIN TEETH

Porcelain teeth afford a more lasting restoration and, when they are used, the method of attaching the denture base must be modified to allow adequate space for the mechanical attachment of the teeth to the base material (Fig. 9). The mesial attachment is formed by a piece of stainless steel wire which projects from the denture base and which is bent for retention in the acrylic resin. The distal suspension is formed by a rod which runs through a slot in the framework and is contained within a tube in the denture base. This tube slopes downward into the den-

ture base, and thus space is allowed for the diatoric teeth (Fig. 10). The fixing of the pin attaches the denture base to the framework, as in the other method of attachment. The male coupling should be waxed into place so that it is in contact with the top of each slot in order that such movement of the denture base as is allowed occurs toward the tissues (Fig. 11).

DISCUSSION

The denture design which has been described was evolved in an attempt to overcome the disadvantages of conventional free-end removable partial dentures.

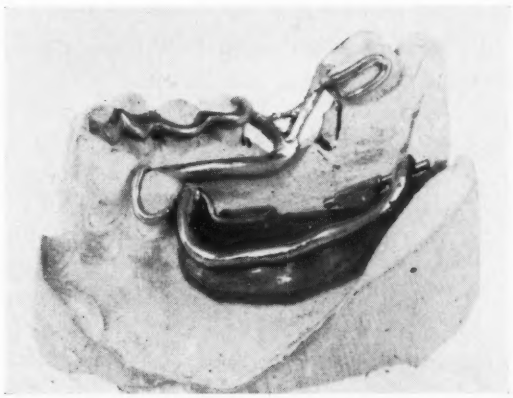

Fig. 10.—The retaining lugs are waxed into position prior to arranging the teeth. Note the downward slope of the distal tube which allows space for the teeth.

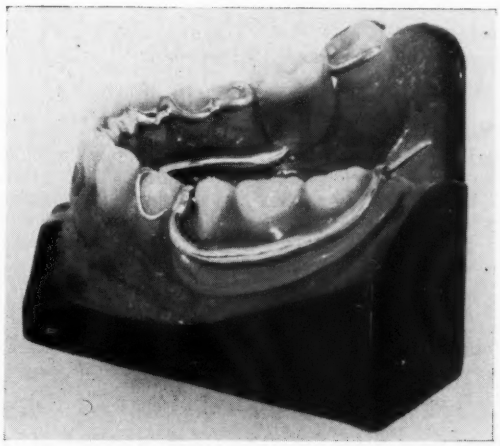

Fig. 11.—A completed denture showing the retaining pin protruding from its channel. Note that there is no acrylic resin collar projecting behind the distal attachment to afford a means of permanent anchorage. Instead, the wire is cut so that approximately 2 mm. projects beyond the distal retainer unit. The wire is heated and pushed into the acrylic resin of the denture base to achieve permanent fixation.

Originally, it was thought that the bars supporting the denture base would be poorly tolerated and, for this reason, the lingual portion was omitted in some cases. It was found that this omission allowed a lateral rotation of the denture base to occur, and the border of the buccal flange became embedded into the soft tissues producing ulceration or hyperplasia. While this rotation could have been prevented by altering the shape of the metal insert which formed the male portion of the coupling, it was noted that lingual and buccal supports used together are well tolerated and that they prevented this rotation from occurring. It was expected that food impaction might occur between the supporting bars and the acrylic resin denture bases, but the patients who have been questioned specifically about this point state that they do not find that these dentures become unduly contaminated with food debris, and this is borne out by inspection of the dentures in situ.

Those patients who had previously worn dentures of conventional design were enthusiastic in their praise of this type of appliance.

This type of appliance may be used in conjunction with tooth-bounded denture bases, or two free-end denture bases may be restored in this manner. In one patient whose posterior teeth were missing from both sides of the mouth and irradiation of an epithelioma had resulted in a small area of osteo-necrosis on one side, the other side was satisfactorily restored by a unilateral denture of this type.

SUMMARY

The adverse changes which occur in the mouths of patients whose lower posterior teeth have been lost are considered, including those charges attributable to removable partial dentures of different types.

Various aspects of removable partial denture design have been considered in relation to the problem of minimizing this tissue damage.

Finally, a new concept has been presented in which independent movement of each denture base is allowed to occur. This movement provides for the even displacement of the underlying mucosa and avoids the effect of stress concentration which follows the early loss of residual alveolar bone.

I would like to thank Professor H. R. B. Fenn for his many helpful suggestions and the kind interest he has shown in the preparation of this article. I am grateful to Mr. J. H. Cragg who has carried out all the technical work and who evolved the simple method of construction now used. I am indebted to Miss Whitely of the Dental Photographic Department for the photographs and to the Department of Medical Illustration for the diagrams.

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FIXED PARTIAL DENTURES

PORCELAIN FUSED TO GOLD

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THE INTRODUCTION OF CERAMIC porcelains which can be fused directly to gold castings is a tremendous step forward in dentistry. Experience, but no extraordinary degree of skill, is required to handle these materials satisfactorily, and the techniques require no special or elaborate equipment. Laboratory procedures are best carried out in the dentist's own laboratory and under his personal supervision, and these materials permit this procedure.

Porcelain materials that can be fused to gold have been available for quite some time, and yet there is little reference to them in the literature. There have been, however, two excellent articles on this subject in the JOURNAL OF PROSTHETIC DENTISTRY. Brecker[1] describes a product with which I have no experience, and Johnston and others[2] discuss the Ney product and give an excellent description of its physical properties, techniques used, and some clinical results.

In considering the usefulness of this porcelain, I experienced considerable difficulty in achieving a worth-while esthetic result, at first. However, experience and practice have improved the results considerably, and I now employ this porcelain as the material of choice for all crowns except for the central and lateral incisors in young patients. No translucent porcelain is yet available for patients in this age group, but the manufacturers have some experimental powders which show promise.* When such a powder is available, we may be able to match the esthetics of full porcelain jackets for these central and lateral incisors.

SHADE

The manufacturers supply formulae for matching New Hue shades. However, I have found these to be unsatisfactory and have made up a shade guide of my own. To do this I cast a series of flat pieces (roughly the outline shape of an upper central incisor 32 gauge in thickness). The pieces are cast in the alloy with a narrow extension from the back to serve as a handle. To these pieces of gold I have baked a progressive series of shades, striving to match the Candulor (Swissedent) shade guide. If I do not have a shade to match a particular tooth,

Received for publication July 29, 1957.
*R. Coleman (J. M. Ney Co.): Personal communication, April 11, 1957.

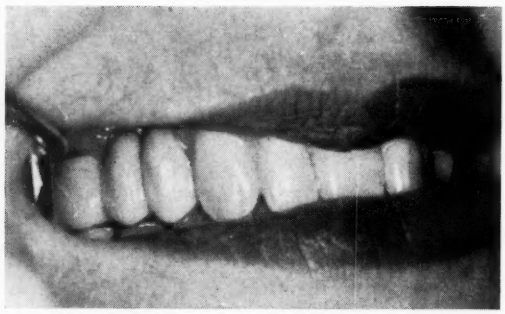

Fig. 1.—An upper four-unit fixed partial denture—cuspid to first molar. The abutments are full coverage crowns. Visible metal is limited to the collar of the molar coping and the lingual surface of the cuspid casting. The cuspid has a full porcelain incisal surface and no metal collar on the labial surface. The technique of "butting" the porcelain to the shoulder of the preparation on a labial or buccal surface is described by Brecker.[1]

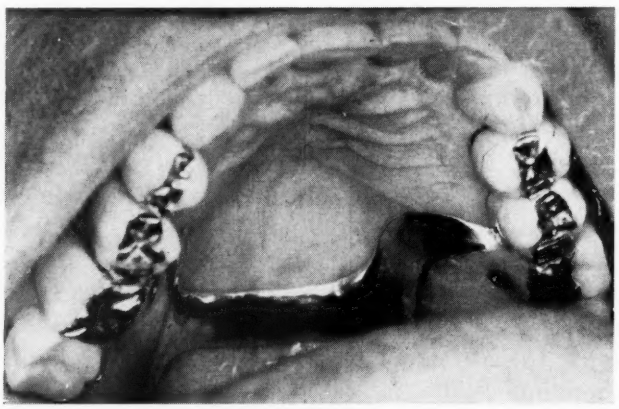

Fig. 2.—An upper bilateral distal extension removable partial denture. The abutments are splinted full coverage crowns on first and second bicuspids. Note the gold occlusal surfaces of the abutments and the gold with a buccal porcelain surface used to cover the stress-breaking attachments on either side.

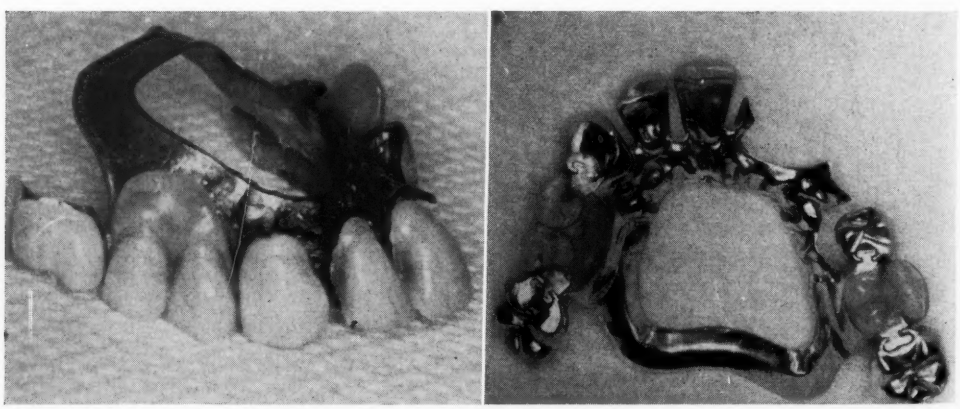

Fig. 3.—An upper removable partial denture with its abutment crowns. The left second molar, first bicuspid and cuspid, right cuspid, and second molar were all used as full coverage abutments. The left central incisor has a distolingual inlay with a nonprecision slotted rest.

I can get an approximate idea of what shade I need and make up a few new shades to approximate it. By this means, I have an extensive range of formulae available, and with the judicious use of S.S.W. 1,600° F. stains and overglaze, I can meet my requirements reasonably well.

INDICATIONS FOR PORCELAIN FUSED TO GOLD

The porcelain fused to gold materials are especially indicated for: (1) anterior jacket crowns where the occlusion, or posterior support, is such that regular full porcelain jacket crowns are contraindicated, (2) all posterior jacket crowns, (3) all abutments for fixed partial dentures where full coverage is indicated, (4) pontics for fixed partial dentures, using a technique similar to that suggested by Granger[3] to provide a fully glazed porcelain tissue contact surface with little of the metal exposed, (5) full coverage abutment crowns to carry the occlusal rests and clasps of removable partial dentures, (6) full coverage abutment crowns housing female precision attachments for removable partial dentures, (7) specially designed and constructed facings for particular problems, e.g., to cover the stress-breaker attachment of free-end denture bases retained by precision attachments, and (8) splinting teeth for multiple abutments or periodontal therapy.

FACING FRACTURES

Brecker[1] describes the particular variations necessary in tooth preparation for these restorations. I most earnestly commend his article to those interested. The few cases of fracture (four) which I have experienced have been due to failure to remove sufficient tooth structure from the lingual surface of the upper anterior teeth. The chemical bonding of the porcelain to gold appears to be excellent.[2,4] When a facing "pops off," it is apparently due to a lack of rigidity in the casting. If the casting is too thin, a twisting force is exerted on the porcelain. It is interesting that when this does occur, most of the metal surface from which the porcelain "pops off" is still covered with the opaque, i.e., the fracture is within the porcelain itself and not between the porcelain and the gold. The manufacturers* feel that this "popping off" is due sometimes to too many bakes and to bakes at too high a temperature. The opaque porcelain is overfused and indeed boils which causes voids. This may well be, but I feel that the answer is more mechanical in nature (subjecting the porcelain to a tensile force to which it is well known to have little resistance).

CAST COPINGS

The exact shape of the ideal preparation for a porcelain jacket crown is well known. Unfortunately, in practice we often have to prepare an extremely broken down tooth. This requires building up the crown with reinforced amalgam (as suggested by Markley[5]) before we cut the jacket preparation. Even then the result may be far from ideal for full porcelain coverage. However, when porcelain

*R. Coleman (J. M. Ney Co.): Personal communication, June 4, 1956.

is fused onto a cast gold hood or coping which can be shaped as ideally as our ability to carve wax permits, there is little or no excuse for applying porcelain to anything but ideal mechanical conditions.

PRECISION ATTACHMENTS

Precision attachments can be soldered to the gold alloy onto which the porcelain is baked. While the actual task of soldering is more difficult because of the fusing range of 1,800° to 1,830° F., we have had no trouble. Not once has an attachment moved or warped either during soldering or in the subsequent baking of the porcelain to the metal structure.

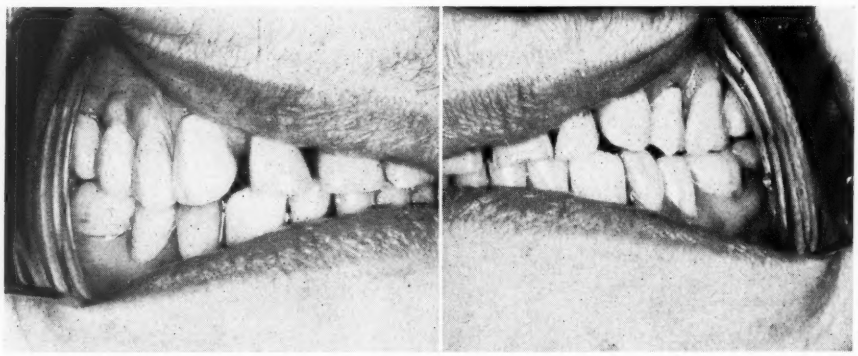

Fig. 4.—Right and left views of this upper partial denture in the mouth. The lower cuspids are also porcelain fused over gold crowns, and serve as abutments for a lower distal extension partial denture.

FIXED PARTIAL DENTURES

In designing fixed partial dentures where porcelain is to be fused to gold, the emphasis should be on obtaining rigidity in the casting. Tylman[6] analyzes the stress to which a porcelain fixed partial denture is subjected and gives excellent recommendations for the placement of the metal reinforcement. Likewise, Granger's[3] design of platinum iridium castings to take porcelain and the details of building the porcelain pontics merits study.

Johnston and others[2] have discussed the techniques to be used with these materials, but I feel that it is probably safer to keep the opaque bake to 1,450° F. instead of 1,500° F. and to use S.S.W. 1,600° F. overglaze with distilled water and not that supplied by the manufacturers.

CLINICAL RESULTS

During a 15-month period, 16 fixed partial dentures of varying sizes utilizing different types of abutment crowns constructed of porcelain fused to gold have been inserted (Figs. 1 and 2). During this same period, 141 jacket crowns of many types constructed of porcelain fused to gold have been inserted. Of these,

47 carried soldered female precision attachments (Fig. 3). Esthetically and mechanically, these restorations have proved to be extremely satisfactory (Fig. 4).

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GINGIVECTOMY AND CROWN PREPARATION IN OCCLUSO-REHABILITATION

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MOST PATIENTS REQUIRING complete or partial rehabilitation of the mouth present themselves with disturbed and, in many instances, badly broken down periodontal structures. These patients have gone through stages of missing and drifting teeth which have changed the occlusion drastically. The centric, protrusive, and lateral occlusal positions have become accommodated to a malfunctioning set of teeth, and their replacements, both fixed and removable, are constructed to these incorrect positions. In many of these patients, the breakdown of the periodontium proceeds until the end result is an edentulous mouth.

In rehabilitating these badly broken down mouths, it is very effective to make preliminary preparations of the teeth for veneers for a quadrant or a half of the mouth during each visit. After the bulk of the crown is prepared, and during the same visit, gingivectomy is performed where it is indicated. It is possible to obtain a simple approach to the proximal pockets after the preparations are started. If there should be an infrabony pocket on the proximal surface and an indication for the surgery of this area, the opportunity for completely cleaning out the area is vastly improved and, in many instances, there may be a visible approach to the pocket. Even if there are narrow tortuous pockets, the technical problem of instrumentation is simplified.

From the patient's point of view, a gingivectomy done during the prosthetic phase is also an improvement. There is excellent local anesthesia. The patient does not require more office visits than the time necessary to complete his prosthesis, and there is no duplication of effort.

From the dentist's point of view, after the gingivectomy is completed, temporary splints can be constructed so that centric occlusion is obtained, and the proper protrusive and lateral components of occlusion are developed. This begins the treatment phase for the periodontium immediately, and it is an excellent test to determine the future maintenance of any questionable teeth. If the periodontium responds within a reasonable time (one to three months), then questionable tooth or teeth may be utilized as abutments if they have been so indicated in the treatment plan. If, after a fair test, there is a negative response, the best approach is extraction of the questionable teeth, and an alternate plan must be accepted.

The time of healing with the above procedure is at least equal to that of a gingivectomy performed prior to the crown preparation. The clinical result is also equally favorable, and patients have not shown any unusual discomfort during or after the combined operations. A rehabilitation can be completed with a similar end result in a much shorter time in this way than by doing it separately.

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Received for publication Nov. 21, 1957.

A CLINICAL STUDY OF THE BENNETT MOVEMENT

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THE BENNETT MOVEMENT WAS originally described by Norman Bennett in 1908.[1] The experiment in which the movement was first noted was an interesting one. He attached a framework of wires to his own lower teeth by means of bands. This was accomplished in such a way as to permit lateral jaw excursions without interference with the articulation. One wire held a small incandescent glow lamp adjacent to the right condyle. His head was held stationary by a device which allowed only the mandible to move. A biconvex lens was placed between himself and a nearby wall. The lens was brought into focus and the image of the lamp, though upside down, was plainly seen on the wall. A paper was pinned to the wall so that the movement of the lamp, which denoted the movement of the right condyle, could be traced on the paper. As he faced the wall and moved his mandible in excursive movements, he noted that, during an excursion of the mandible to the right, the condyle that should have remained stationary in the fossa actually shifted laterally and downward. His assistant traced this side shift on the paper, and the results were published. At that time he did not realize the tremendous importance of his find since it was not deemed essential to register and duplicate jaw movements, such as the side shift, in restorative procedures.

The Gnathological Society and those who follow their philosophy of practice have been able to register the Bennett movement and actually reproduce it on an anatomic articulator. McCollum[2] has recorded the research that was done to construct the equipment necessary for such exact registrations. In recent years, many authors have been able to describe the Bennett movement lucidly so that our understanding of it has progressed.

Granger[3] portrays this side-to-side movement as "the path of travel of the center of rotation across the glenoid fossa as the condyle is rotating on the meniscus while it is gliding across the fossa." Sicher[4] explains that "a lateral shift of the mandible results if only one condyle and disc are pulled forward and downward and medially to the height of the articular tubercle." Lucia[5] ties in the importance of recording the Bennett movement with the proper articulation of the teeth. Page[6] describes the Bennett movement as a component of the natural functional jaw movements.

Received for publication Aug. 22, 1957; revised by the author Oct. 22, 1957.

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The Bennett movement is a component of the more complex excursive movement. The other components are rotation and translation. Rotation occurs between the condyle and the meniscus and can occur in the horizontal, frontal, or vertical plane. It is not a pure movement in function, but the patient can be instructed and guided to create a pure rotary movement in the vertical plane. Translation is the movement of the condyle down the articular eminence. In a protrusive movement, both condyles move in translation. In a lateral excursion, one condyle remains in the fossa while the other moves in translation. During the opening movement of function, rotation and translation occur in combination. If there is a Bennett movement, it will occur during the excursive movements.

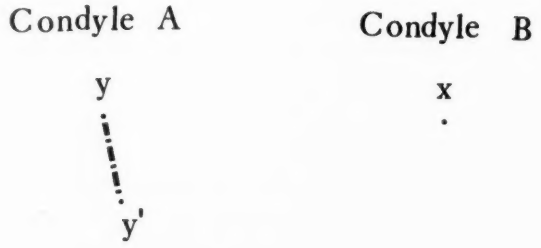

Fig. 1

Fig. 2

Fig. 1.—Diagrams of condylar movement. The symbol (x) represents the center of the rotating condyle (B). The symbol (y) represents the center of translating condyle (A) at the start of the movement or centric relation position. In a zero degree Bennett, point (x) rotates with a fixed center as condyle (A) travels from point (y) to point (y') which is the extreme position.

Fig. 2.—In a condyle with a Bennett movement, the rotating center of condyle B moves from point x to point x' as condyle A moves from point y to point y''.

A description in detail of an excursive movement will explain when and how the Bennett movement occurs (Fig. 1). At an extreme position of an excursive movement, condyle A is perched on the lower anterior medial portion of the eminentia and condyle B is either at its terminal position in the glenoid fossa or slightly displaced from its terminal position. During the movement, condyle A moves up the eminence toward its terminal position. As condyle A moves in this direction, condyle B can either (1) move in a pure rotation to assume its terminal relationship, or it may (2) rotate and move bodily toward its objective. The rotation oc-

curs between the condyle and the meniscus, and the bodily shift occurs between the meniscus and the glenoid fossa. This bodily shift of the condyle and meniscus in unison is the Bennett movement. It can occur in (1) a straight path or (2) a curved path. In Fig. 1, condyle *B* has no Bennett movement; in Fig. 2, the condyle has a Bennett movement. In Fig. 2, the Bennett path is a straight one.

RECORDING THE BENNETT MOVEMENT

A clinical instrument which is used to record the Bennett movement is the Gnathograph (Fig. 3). This instrument was developed by the Gnathological Society of California for the purpose of accurately recording excursive mandibular movements. The Bennett movement, as a component of the excursive movement, can be clearly recorded with the aid of this clinical instrument. It does so at the approximate level of occlusal contact.

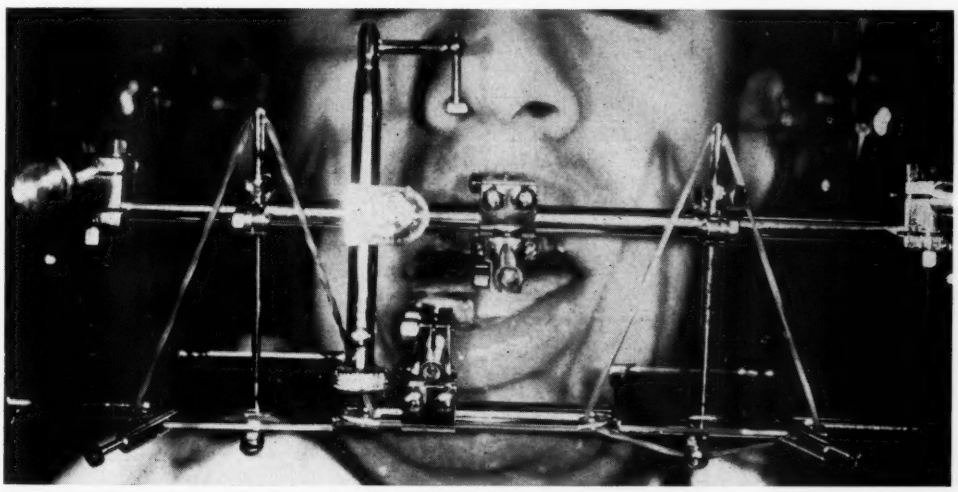

Fig. 3.—The Gnathograph is in position on a patient. This instrument is used to record mandibular movements.

The Gnathograph consists of two face-bows which are attached to the teeth by means of aluminum trays called clutches. The clutches are cemented to the teeth by means of a temporary cement. They have a central bearing plate and screw arrangement for the purpose of eliminating tooth interferences. Glass slides and stylus points are arranged in strategic areas to record the movements in all three dimensions. Two slides are located in the anterior region (one on either side of the symphysis) and record the movement in the horizontal plane. Needle point tracings of these movements appear as typical Gothic arch tracings. Two slides are located against the skin in the condylar region and record the movement of the condyle path in the sagittal plane. The slides that are of particular interest to us in this study are the diagonal slides in the condyle region that record the path of the condyle in the Bennett movement. A thin film of carnauba wax was placed on the glass slides. The stylus points traced the various movements on the glass slides.

Upon completion of the record, the scratched portion of the slide was etched with hydrofluoric acid. This leaves a permanent record of the movements on the glass slides.

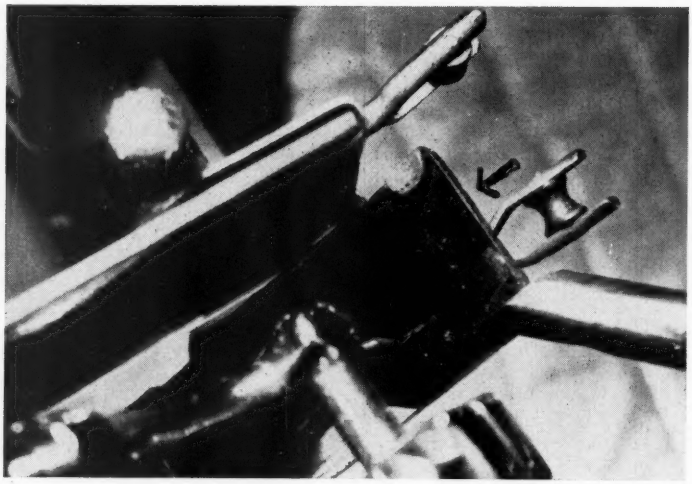

Fig. 4.—The slide placed diagonally between the frontal and the horizontal planes on the outside of the face near the condyle was most suitable for the clinical study of the Bennett movement and is indicated by the arrow.

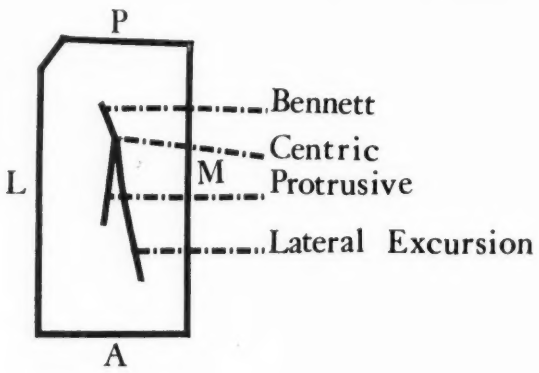

Fig. 5.—A diagram of the diagonal slide near the condyle which was used in this clinical study of the Bennett movement. *M* represents the portion of the slide closest to the face, or the medial portion. *L* represents the outside or lateral portion of the slide. *A* represents the anterior portion. *P* represents the posterior edge of the slide.

The Bennett movement will affect the tracings on all six glass slides. The slide placed diagonally between the frontal and the horizontal plane on the outside of the face near the condyle (Fig. 4), however, shows this movement most clearly. It shows three lines meeting at one point (Fig. 5). This junction represents the meeting point of three movements and is centric relation. The shorter outside line below the junction represents the protrusive movement.

Both protrusive lines on the right and left slide are made simultaneously. The longer medial line is the excursive movement of the condyle as it travels from its position on the eminence toward centric relation. The medial line is made by the balancing condyle and the short line above the junction is made by the working condyle. This holds true for the reverse sides as well. The actual recordings of these lines are made in cooperation with the patient. The patient is requested to make a protrusive movement and the two lateral lines below the junction are made simultaneously. A right excursive movement is then requested, and the medial line below the junction is made on the left slide and the short line above the junction is made on the right Bennett slide. The final movement is the left excursive movement. The right medial line on the right slide and the short line above the junction on the left slide complete the tracing on the slides.

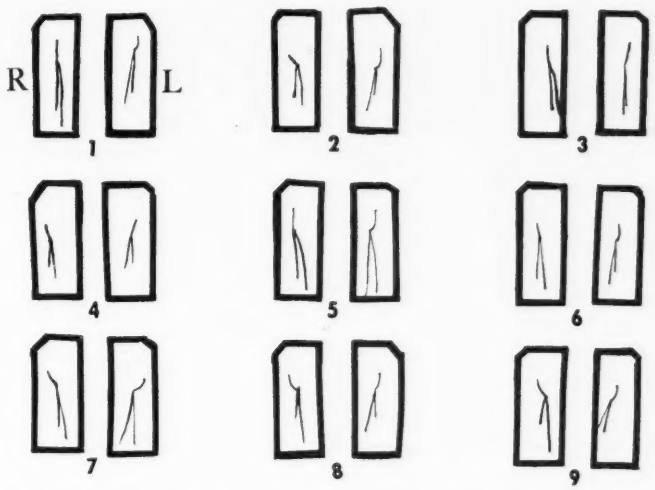

Fig. 6.—Bennett slides traced from the original glass slides of 9 patients having jaw movement registrations made with the Gnathograph. *R*, the slides with records of the movements of the right condyle. *L*, the slides with records of the movement of the left condyle.

From the above description, it is quite clear that the short line above the junction is made by that condyle remaining in the fossa as the opposite or balancing condyle moves from the eminence to centric position. It therefore represents the movement of the working condyle and can be considered as the record of the Bennett movement. The word "represents" was used because it is not the actual movement. The condyle does not move the same distance as the tracing indicates. Just as the markings left by a crystographic ink writing recorder of muscular movements must be interpreted for an electromyographic analysis, so do the tracings recorded on these slides have to be analyzed.

Several sets of Bennett slides are illustrated (Fig. 6). These are tracings from clinical patients and demonstrate the variety of paths that can be expected.

If the right condyle on the working side merely rotated on the meniscus without any bodily shift, then that portion of the tracing on the right Bennett slide would have a straight line without any appreciable angulation. The portion of the tracing that will demonstrate this is the small line above the junction. The discussion in the next few sentences will center about this portion only. This type of recording is illustrated by the right condyle in set 5 (Fig. 6). The Bennett path angle of this slide was zero, which can be interpreted as follows: As the left condyle moves toward centric relation, the right condyle merely rotates (in the horizontal plane) on the meniscus and does not move bodily. The right condyle of set 2,

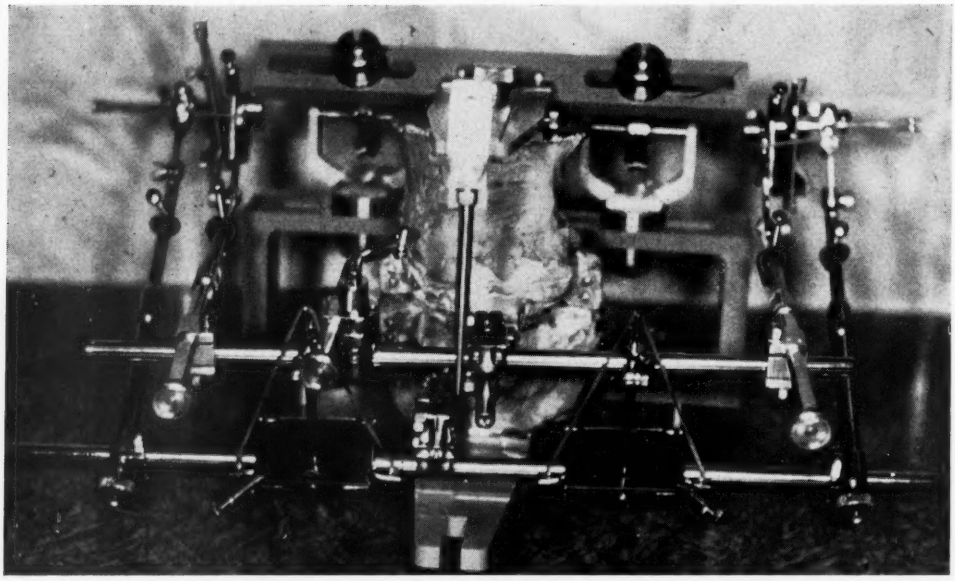

Fig. 7.—The Gnathograph is mounted on the articulator. The Gnathoscope will be adjusted to follow the paths that the patient recorded on the glass slides.

on the other hand, shows a distinct angulation. This condyle has a straight path side shift, or Bennett movement. As the condyle rotates in the fossa, it also moves bodily toward its objective. The left condyle also displays an angulation but the path shows a distinct curve and should be differentiated from its mate for this very reason. In our reproduction of the Bennett path on an articulator, the Gnathoscope, this curved path requires special consideration in that the curve that is made must be literally ground into the Bennett wing or control.

The previous description has been designed to illustrate the background and the nature of this clinical study. Jaw registrations were made on 26 patients. These were patients who required oral rehabilitation because of advanced caries, periodontal disease, missing teeth, the esthetic factor, and malocclusion. These registrations were made preliminary to complete reconstructions of the patients' occlusal relationships. The recordings were made on the Gnathograph, mounted on the Gnathoscope (Fig. 7), and this articulator was adjusted to follow the same paths

that were recorded from the patient. One of the adjustments so made was the angulation and curvature of the Bennett wing of the articulator (Figs. 8 and 9). The angulations of the Bennett movement for 26 patients are recorded in chart form[7] (Table I) with the patient's number, age, sex, Bennett angle, and path radius. The average Bennett angle on the left side was 10.15 and on the right side 14.5. The over-all average path was 12.33 degrees. There appears to be no re-

Fig. 8.

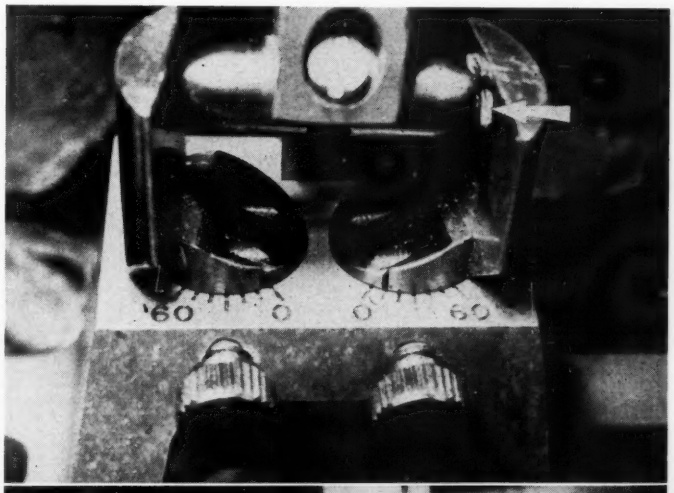

Fig. 9.

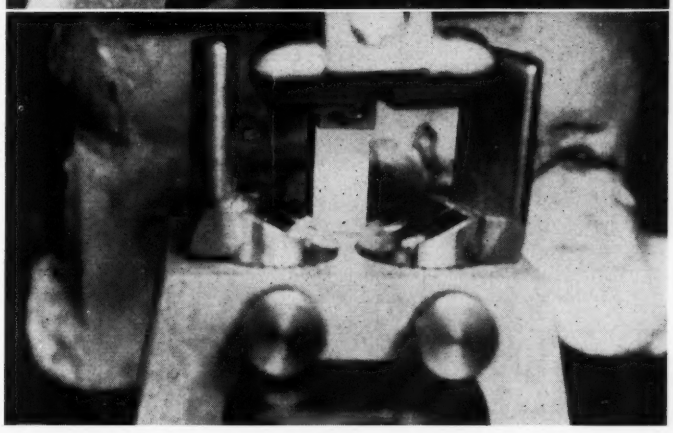

Fig. 8.—A close-up of the Bennett wing of the articulator adjusted to allow it to follow the path created by the Bennett movement. By adjusting the angle of the Bennett wing on the articulator, the instrument can be made to follow a straight Bennett path. If there is a curve to the Bennett path, the metal wing must be ground (arrow) to the shape of the curve. An individual path must often be created in the instrument to duplicate the patient's Bennett movement. In this patient, one side has a 5 degree Bennett angle and the other has a 9 degree angle.

Fig. 9—During an excursion the Bennett guide of the upper arm of the articulator is held against the Bennett wing of the lower arm of the instrument. This will permit a controlled Bennett movement.

lationship between the patient's age or sex and the Bennett path encountered. An obvious conclusion of this study is that all the patients encountered had a Bennett movement in at least one condyle. It is a rarity to find a patient without a Bennett movement. Ten patients had straight paths in both condyles. These patients had less angulation than the patients with curved paths. Their average angulation was 8.5 degrees. Seven patients had curved paths in both condyles. Their average angulation was 17.4 degrees. The range of Bennett path angulation was zero degrees to 35 degrees.

TABLE I. CHARACTERISTICS OF THE BENNETT MOVEMENT IN 26 PATIENTS

PATIENT	AGE	SEX	BENNETT PATH ANGLE		BENNETT PATH SHAPE	
			LEFT	RIGHT	LEFT	RIGHT
1	23	M	8	15	S	C
2	42	M	30	5	C	S
3	56	F	8	15	S	S
4	35	M	15	12	S	S
5	36	M	0	25	S	C
6	39	F	4	2	S	S
7	45	F	0	20	S	C
8	54	M	0	5	S	S
9	55	M	13	15	C	C
10	56	M	18	0	C	S
11	41	M	12	20	S	C
12	46	F	6	8	S	S
13	23	F	20	12	C	S
14	30	M	15	23	C	C
15	45	F	6	10	C	S
16	19	M	18	18	C	C
17	46	M	12	17	S	S
18	59	M	20	25	C	C
19	60	M	10	20	S	S
20	41	F	10	0	S	S
21	22	F	8	35	C	C
22	56	M	10	13	S	C
23	57	F	5	15	S	S
24	36	F	0	5	S	S
25	40	F	8	10	C	C
26	55	F	6	10	C	C

SUMMARY

A clinical study was made of the Bennett movement utilizing the Gnathograph and the Gnathoscope. The following conclusions were possible from this study:

1. The average Bennett angle of 26 patients ranging in age from 19 to 60 years was 12.33 degrees.

2. The average Bennett angle of those patients with both condyles exhibiting straight paths was 8.5 degrees. The average angle of those patients with both condyles having curved paths was 17.4 degrees. It was felt that patients exhibiting greater Bennett angulations had a tendency toward curved paths.

3. The range of Bennett path angulation was zero degrees to 35 degrees.

4. All patients in this group had a Bennett movement in at least one condyle.

5. There appears to be no relationship between the patient's age or sex and the Bennett movement.

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OPERATIVE DENTISTRY

ELASTIC IMPRESSION MATERIALS— A SUMMARY OF A RECENT CONFERENCE AND ANALYSIS OF THE CURRENT STATUS AND RECENT RESEARCH

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THE INTRODUCTION OF THE THIOKOL and, more recently, the silicone impression materials has stimulated a keen renewed interest in the use and merits of the elastic-type impression materials. A one-day seminar of the Committee to Investigate Elastic Impression Materials† was devoted to an analysis of the current knowledge of the newer materials as well as a discussion of recent research on the hydrocolloid type materials. The papers were presented by technical representatives from dental manufacturers, the dental profession, dental schools, and the National Bureau of Standards. The list of the essayists and their topics may be found at the end of this article.

In view of the widespread interest in this field and the conflicting statements which have arisen, the author was requested to prepare a short summary of this meeting. It must be recognized that such a task cannot be entirely objective. However, a sincere attempt has been made in this article to summarize the general consensus, not necessarily the exact views of the author or of specific individuals. Likewise, it must be remembered that certain of the discussions were quite informal and often of a confidential nature. Such matter has obviously been eliminated from this article. However, this omission does not detract from the more tangible and direct laboratory and clinical findings which were presented.

It is not possible, with the space limitations, to present an analysis or résumé of each individual paper. Since many of the papers and the ensuing discussion overlapped, only a composite general summary of the meeting will be presented. Likewise, no attempt will be made to document each conclusion. The author has taken the liberty of adding some literature references which substantiate some of the more pertinent statements and conclusions which evolved. These references also provide a source for further reading if desired.

This committee has functioned through the years in stimulating research and analyzing the data obtained on investigations concerned with the hydrocolloid type of materials and the auxiliary materials employed. Now with the advent of other types of elastic impression materials, the area of interest has been expanded. It

Reprinted from the Journal of the Southern California State Dental Association 25:28-33, 1957.
Received for publication Sept. 23, 1957.
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†Chicago, Ill., Feb. 1, 1957.

is not the purpose of the organization to direct, regulate, or evaluate research or specific materials, but rather to afford an impetus and coordination for the development of better techniques, both from the standpoint of laboratory test methods and clinical application of the material.

RUBBER BASE IMPRESSION MATERIALS

The problems which are involved in the development and manufacture of any new dental material are especially magnified in the rubber base, Thiokol, impression materials. The dental manufacturer does not make the basic chemicals but rather compounds and modifies them. The differences between the final commercial products will then be due to modifications of essentially the same raw material. Typical problems involved are the source and dependability of the supply, uniformity of batches, progression from pilot to commercial lots, stability of the product and the package, toxicity, accuracy and dimensional stability, allergic reactions, etc. Thus, although all of the present rubber impression materials are based on the same Thiokol polymer from a common source and though all do use the same basic system of curing, each product will differ in many respects.

In the dental rubber base impression material, one tube contains a paste of the mercaptan known commercially as LP2. This compound contains extremely reactive SH terminals on the molecule.[1,2,3] Polymerization through these groups can be accomplished by means of various accelerators. In general, lead peroxide is used, and it is contained in the second tube of material, usually with small amounts of sulfur. The volume concentration of the Thiokol and lead peroxide are approximately equal. Although originally some concern was expressed about the possible toxic effect from the lead, all evidence indicates complete safety. The lead compound is of low solubility and is thoroughly imbedded in the rubbery mass so that even in case of ingestion, no particular hazard can arise. Other agents are also added, such as zinc oxide, stearic acid, and calcium sulfate, to regulate certain properties. The basic compositions of these materials have now been well established, and fluctuations in batches should no longer be a problem.

Equally important are the many variables associated with their use. These have now been studied, something of a standardized procedure established, and proper armamentarium developed. The use of a syringe for injecting the rubber material into the cavity preparation minimizes bubble formation and would seem to be as essential to the use of this material as to hydrocolloid.[4] Minimizing bubbles is imperative not only to assure maximum detail but to prevent subsequent distortion due to collapse of the bubbles. Likewise the use of a material having two consistencies, a thin-bodied one for the cavity preparation and a heavier-bodied material for the tray or band, assists in preventing entrapped bubbles and produces maximum accuracy.

There was, and has been, much discussion concerning the relative accuracy between this type of material, the silicone impression materials, and hydrocolloid. One of the complicating factors in this field is the lack of a standard recognized laboratory test for such evaluation. Whether such a test, acceptable to all, will ever evolve is debatable. However, the composite data available which have made use

of different test methods, such as measurements on the material itself or the resultant stone dies and the fit of master castings, all lead to some general observations pertinent at this time.[4-9] It is well to point out, though, that the clinical evaluation of any impression material will long remain controversial, and there is no short cut or substitute for abundant research data, both laboratory and clinical, from many sources. The standards of accuracy felt to be necessary, the specific type of die employed to predict the relative accuracy, the ability of the operator to handle the material, and above all, the integrity of the investigator or operator in approaching the question without bias all influence the results.

Relative to this entire matter of "how accurate must the impression be," the consensus seems to be that there are certain tolerances, and fortunately so, in the clinical restoration. However, every dental operation must be beamed for a goal of minute perfection, even though it may be impossible to attain. Any lowering of such standards can only lead to deterioration and lack of progress. Thus, rigid laboratory tests would seem to be imperative in investigations of such materials and the results of such investigations should then be carefully correlated with clinical dental techniques.

No attempt was made at this meeting to establish, by consensus, any relative degree of accuracy of the various classes of impression materials. It is apparent that the accuracy of the rubber base materials is in the same realm as reversible hydrocolloid, and that this class of impression materials may be considered satisfactory for routine indirect techniques of a complex and meticulous nature. Lack of clinical success can only be attributed to improper manipulation and use of the material.

VARIABLES

Some of the variables which are now recognized and which contribute to the accuracy of the material will be briefly discussed. Setting time of the material is influenced by both humidity and temperature—the higher the humidity and temperature, the more rapid is the set. The material must be held tenaciously by the band or tray and suitable rubber cements will do the job nicely. The band or tray must be rigid to prevent distortion upon removal, and they should be adapted to permit the use of minimum amounts of material. Contrary to hydrocolloid, bulk of the rubber is not desirable.

One of the most common causes for failure is removal from the mouth too soon. The curing continues for some time, and it is most important that adequate polymerization take place before the impression is removed. Thus, the *minimum* length of time from the start of the first mix until the impression is removed would be 10 minutes—representing at least 6 minutes with the tray seated in the mouth.

The most controversial subject, and one widely publicized by many manufacturers, is the unique dimensional stability of the material. Some research has indicated that there is apparently good stability of the impression while other investigations have been contradictory. Here again the method of evaluation is highly important. Whether the master die involves undercuts, its size and taper and the number of specimens studied all influence the investigator's evaluation. If the fit of a master casting on a stone die is used as the criterion for evaluation, the

exact fit expected and deemed necessary is highly important. Because of these variables, no uniformity of opinion has yet evolved. There is no doubt, however, that some dimensional change does occur with time.[8,9,10] These changes are due to continued polymerization and to release of internal stress. Although there is probably somewhat greater leeway in this regard than with the use of hydrocolloid, due to no imbibition or syneresis problems, it would still seem advisable to pour the impression within the first 2 hours. The safety range beyond this interval is still to be questioned.

The surface of stone casts poured in these materials and the reproduction of marginal detail is excellent. The impressions can be electroplated, but insufficient data are available to determine the effect of plating on the accuracy.

Future research with this class of materials will center on clarification of the dimensional stability, perfection of the handling characteristics, application of the material to prosthetic dentistry, and the development of an A.D.A. specification.

SILICONE

Although used for several years in Germany, the silicone type of impression materials has only recently been introduced to America. Their manufacture presents even more problems than the Thiokols. Small amounts of the catalysts are used, and their distribution evenly throughout the vehicle is difficult. A more basic problem is the lack of knowledge supplied by the chemical manufacturer to the dental company. As the dental manufacturer must often assay the raw material as best he can or work with little information about the chemical composition, progress has not been easy. Since the exact compositions are not well known and are closely guarded secrets, no discussion will be given to this facet. The formula, of course, contains the element silicone, and polymerization occurs through the connecting hydroxyl groups. Curing is probably accomplished by a catalyst such as benzoyl peroxide. Although the working time of some of the early silicones was inadequate, recently materials have been developed which have setting times that are slow enough to permit the use of syringes and a double mixed technique. Another early difficulty, particularly with the German raw material, was the liberation of hydrogen gas and a subsequent inferior stone surface. This problem can be controlled by modification of the formula.

Because of their newness, few data are readily available in regard to their accuracy, stability, and the many factors which contribute to their success or failure. It is obvious, though, that their lack of offensive odor or color and their cleanliness and ease of manipulation are advantageous. Their cost is somewhat higher than the Thiokols. (This higher cost of both types of materials will probably not be reduced in the near future since the raw materials themselves are not inexpensive.)

Observations on accuracy differ with various investigators and with brand of material—some getting superior and others inferior results compared to hydrocolloid or to the Thiokols. The same may be said of dimensional stability. No conclusions were derived, although it was generally agreed that their future possibilities, and in particular their handling characteristics, are impressive.

The techniques for their use apparently are essentially the same as for the Thiokols. Most of the manipulative variables have not as yet been studied, but it is probable that the same factors which influence the Thiokol materials also contribute to the success or failure of the silicones.

REVERSIBLE HYDROCOLLOID

The basic chemistry, physical properties, and manipulation of reversible hydrocolloid for dental impressions are all well established, and its contribution to the field of restorative dentistry is epic. Because of their proved success through the years, and the limitations to any possible formula or technique changes, little research is currently in progress with these materials. The basic properties of the dental reversible hydrocolloids are naturally governed by the characteristics of the main agar-agar base. There are some 57 different species of this seaweed, and all have their individual properties. Dental hydrocolloids are invariably a composite of 4 or 5 different types, carefully blended to achieve the necessary gel strength, accuracy, gel point, etc.

Naturally, the greatest single problem with this material, or with the irreversible hydrocolloids, is the rapid loss or gain (syneresis and imbibition) of water if the impression is stored. It has been proved by many investigators that distortion of a definite clinical magnitude may occur within 30 minutes, even in the most ideal storage media (100 per cent humidity). Recent research[11] has indicated that the water change in such cases is actually quite small. The fluctuations may be as low as 0.1 per cent, although it is usually somewhat higher in the outer layers of the impression which are exposed to the environment. Naturally, storage in water or in air produces fluctuations up to 15 per cent within 24 hours. Such data compare well with the studies which have been made on practical dies.

The loss or gain in water is not the only variable which may influence the dimensional stability of the hydrocolloid impression. As mentioned previously, all dental impressions contain a certain amount of internal stress, and any subsequent release then produces a distortion. Although it has been implied that an agar-type material has no stress pattern, recent investigations indicate that stress is present and the amount of stress will, of course, vary with the manipulative technique. Thus it becomes more and more doubtful that it would ever be possible to develop an isotonic solution which would prevent distortion. From a chemical standpoint[12] development of such a solution for storage of the impression has difficulties and would still not prevent possible distortion due to release of stress. Thus, all evidence indicates that there is little possibility of eliminating the necessity of pouring the impression immediately.

ALGINATE

Most commercial alginates have made use of the time-set principle in which the setting time is regulated primarily by the addition of retarding agents. Some study has recently been given to the development of a somewhat different type alginate in which the set would be regulated primarily by thermal change. Such

a product has the advantage of adequate working time at room temperature but a rapid set at mouth temperature. Fast gelation in the mouth is probably always desirable and particularly with the alginates, in order to minimize distortion and increase accuracy. In such a material, it is necessary to utilize a retarder which is relatively active at room temperature but short-lived at mouth temperature. The main disadvantage of such a material is the more critical effect of the water temperature on setting.

Data, of a more technical nature, were presented on the general problem of measuring the gel strength or "development time" and its relationship to setting time. Such data are imperative to the research worker and to those who must evolve specifications and test methods for dental materials. The opportunity of open discussion, such as this meeting, where the relationship of experimental data and test methods to the clinical behavior of the material can be established is most beneficial.

STONE

The stone die itself still remains a fertile field for research. Much still remains to be learned of the dimensional changes which occur during setting, the effect of the various impression materials upon the setting changes and the surface of the die, and the influence of the manipulative variables on the physical properties. New test devices[7] are shedding light on certain of these problems, particularly the effect of water-powder ratio and the influence of hygroscopic expansion. Since it is possible to plate, satisfactorily, the rubber base and silicone impressions, research in this area must be expanded to include these techniques.

CONCLUSIONS

A résumé of a recent one-day meeting of the Committee to Investigate Elastic Impression Materials has been presented. Only the discussions and portions which are not unduly technical and which have some practical and timely value have been included. The activities of this group in stimulating research and in bringing a closer liaison between the manufacturer, research worker, and practicing dentist are commendable.

Many of the variables associated with the Thiokol-type impression materials have now been studied and the compositions standardized. Factors such as use of minimum bulk of material, bonding of the impression material to the tray, adequate time in the mouth, and use of double-mix techniques are essential to accuracy. The newer silicone materials need similar research of this nature, but their handling characteristics and lack of offensive odor or color make them worthy of serious investigation.

Results are still confusing in regard to the exact comparable accuracy of the Thiokols, silicones, and hydrocolloid impression materials. Much of the controversy may be attributed to the variety of test methods being employed, the proficiency of the investigator and the standards for evaluation. Future research must correlate laboratory data with clinical observations and may eventually evolve a suitable universal in vitro test method. However, all evidence indicates that these materials, properly used, compare favorably.

There are as yet insufficient data on the dimensional stability of the Thiokol or silicone materials. They appear to be somewhat superior to the hydrocolloids. However, the continued polymerization and release of stress do influence stability, and with the lack of information available, it would appear to be sound practice to pour the impression within the first 2 hours.

Research now in progress sheds doubt that an isotonic solution for storage of reversible hydrocolloid can be developed. At present, most investigations with the reversible hydrocolloid impressions are concerned primarily with test methods for measuring certain inherent characteristics and physical properties.

PROGRAM OF THE CONFERENCE

"Technical Problems of Rubber Base Impression Materials," W. F. Talbot, Kerr Manufacturing Co.
"A Comparative Report on Some of the Physical Properties of the Rubbery Polymeric Impression Materials (Thiokol and Silicone Type)," E. J. Molnar, Coe Laboratories, Inc.
"Anomalous Behavior of Gypsum Die Materials When Used in Conjunction With Elastic Impression Materials," J. H. Lipscomb, Surgident Ltd.
"Testing Alginate Impression Materials," J. Cresson, L. D. Caulk Co.
"A New Type of Alginate—Emphasis on Thermal Rather Than Time Set," J. Shell, Ransom & Randolph Co.
"The Base Material of Hydrocolloid Agar Agar," W. J. Van Rossem, Van Rossem Co.
"A Study of the Physical Properties of Elastic Impression Materials and Stones," G. M. Hollenback, Encino, Calif.
"Clinical Application of Mercaptan Rubber Impression Materials," C. M. Sturdevant, University of North Carolina.
"Summary on Alginates," W. T. Sweeney, National Bureau of Standards.
"Summary on Silicone Rubber Materials," F. A. Peyton, University of Michigan.
"Summary on Reversible Hydrocolloid," R. W. Phillips, University of Indiana.
"Summary on Rubber Base Materials," E. W. Skinner, Northwestern University.

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INCREASING THE VERTICAL DIMENSION OF OCCLUSION

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INCREASING THE VERTICAL DIMENSION of occlusion is a phase of dentistry that is not practiced extensively. Although certain patients require this type of dental treatment, it is not done in most instances because it is too complicated, because it is too time consuming, or because the possibility of error is very great.

This article will be confined to a discussion of the procedures associated with the increase of the vertical dimension of occlusion.

PRELIMINARY WORK

An oral examination, including intraoral roentgenograms, is essential in determining that the teeth to be used to form the keys of the foundation are teeth with vital pulps, teeth with good bony support, and the only ones which will serve this purpose.

The patient is given an oral prophylaxis, and impressions are made for study casts. These impressions are poured in stone and, when the stone has set, the casts are separated carefully from the alginate or hydrocolloid impression material. A second set of casts is poured in these same impressions. The second cast may prove to be inadequate, in which case the first casts are duplicated.

If there are sufficient teeth on the casts, no interocclusal jaw relation records are made. The casts are fitted together in centric occlusion, using the worn facets on the occlusal surfaces of the teeth as guides. The casts are held together by means of rubber bands or match sticks and sticky wax, and they are mounted on an articulator capable of reproducing anatomic movements. No face-bow measurement is used. All articulator adjustments are set at 0° at this time.

The mounted casts are then studied carefully from all aspects, and notations are made on buccolingual tooth alignment, tooth rotation, uniformity of the planes of occlusion, and individual tooth occlusion. Possible methods of correction are listed for later use (Fig. 1).

The vertical dimension of occlusion is increased sufficiently on the articulator to enable the anterior teeth to come edge to edge, without interference, when the posterior teeth are in right and left lateral working positions (Fig. 2). The anticipated corrections are then made on the mounted study casts.

Inlay wax is added to the occlusal surfaces of the teeth of the study casts to correct the plane of occlusion, to correct buccolingual tooth alignment, and to create

Received for publication April 29, 1957; revised by the author Jan. 16, 1958.

a tooth occlusion that will function in lateral excursions. The first set of study casts is used as a guide in copying the anatomy of the teeth. If there are any teeth missing, they are restored in wax.

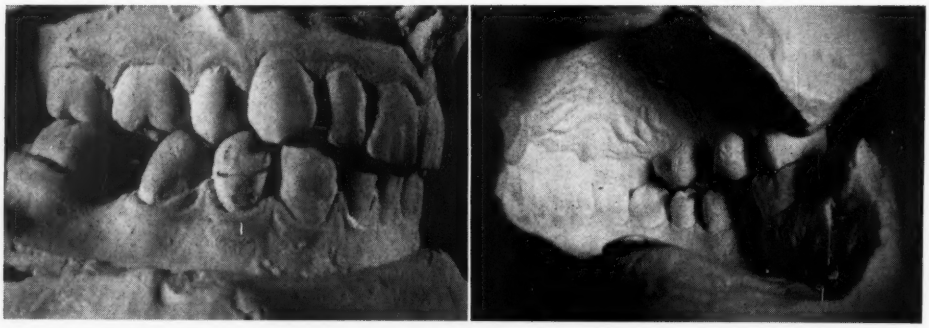

Fig. 1.—The study casts are mounted in centric occlusion. Note the complete lack of occlusion of the lingual cusps of the bicuspids and the deep vertical overlap of the contacting anterior teeth.

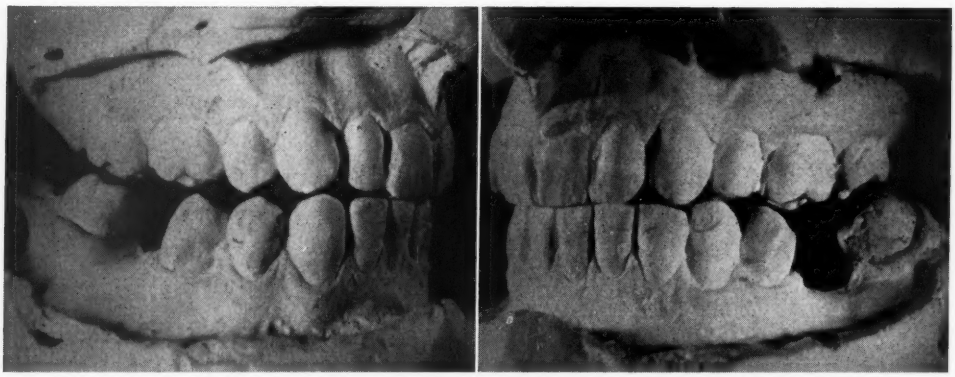

Fig. 2.—The vertical dimension of occlusion is increased sufficiently to permit the anterior teeth to come edge to edge. Note the distance between the opposing posterior teeth.

These procedures should be done as perfectly as possible. It is time well spent to become familiar with the conditions involved by using study casts. A tentative treatment plan is developed which includes all of the operative procedures to be performed on each tooth.

The problems of treatment are discussed with the patient, and this discussion is supplemented by the use of the correct study casts.

OPERATIVE PROCEDURE

With the treatment plan clearly in mind, two or three teeth are prepared at a time, starting either with the first bicuspid or second molar. With few exceptions,

the teeth are prepared for full crowns (with or without veneers) or three-quarter crowns.

Copper band and compound or Dietrich's plastic compound impressions are made for the construction of silver dies. The procedures are repeated at successive appointments until all of the posterior teeth are prepared and individual impressions of each tooth are made.

SILVER DIES

The root extensions of the silver dies are made square, cone-shaped, long enough to be held conveniently, and smooth enough to be easily pushed from the stone sockets. Since these dies must be oriented in the same relationship to each other as the teeth are in the mouth, it is necessary to make copings in metal or acrylic resin that fit the dies as accurately as the teeth. Individual trays are fabricated in order to make complete mouth sectional modeling compound impressions, and an interocclusal wax centric relation record is made.

IMPRESSIONS

The copings are placed on the teeth, and sectional modeling compound impressions are made and removed. The copings are dried with a blast of cold air, placed on the dies, and the dies are reseated into the impressions and secured there with sticky wax to prevent movement while the casts are poured. The root portion of the dies is lubricated lightly to facilitate their removal from the stone casts.

The articulator adjustments are set at 0° and the casts are mounted in centric relation by means of the interocclusal record. Then the articulator is adjusted for the right and left lateral positions as in the preliminary work. If these procedures are done correctly, the casts will be mounted in centric relation, and the vertical dimension of occlusion will be opened to the degree that the patient will be able to shift the mandible to right and left lateral positions without interference from the anterior teeth.

The dies are built up in inlay wax to establish the buccolingual alignment and the plane of occlusion. The study casts, as well as the study casts that have not been modified, are used as guides in shaping the anatomy of the teeth. The teeth are carved into occlusion according to the settings of the articulator (Fig. 3).

WAX SKELETON CROWNS

The wax is removed from the *occlusal surfaces of only the opposing molars* until the silver dies are reached in some spots. The cusp height of the wax crowns must not be lowered and is left very thin with small spines of wax of the individual cusps jutting into the carved cavity, creating a wax "skeleton crown" or framework for the crown. Approximately 0.5 mm. of wax is added all around the border of the occlusal surface of the wax crown, and if it is to be a veneer crown, or if it is to carry an attachment, a space is created for that purpose (Fig. 4).

GOLD SKELETON CROWNS

A hole is cut in the deepest part of the wax skeleton crown. This hole will accommodate a good size sprue and thus allow the casting of the occlusal surface

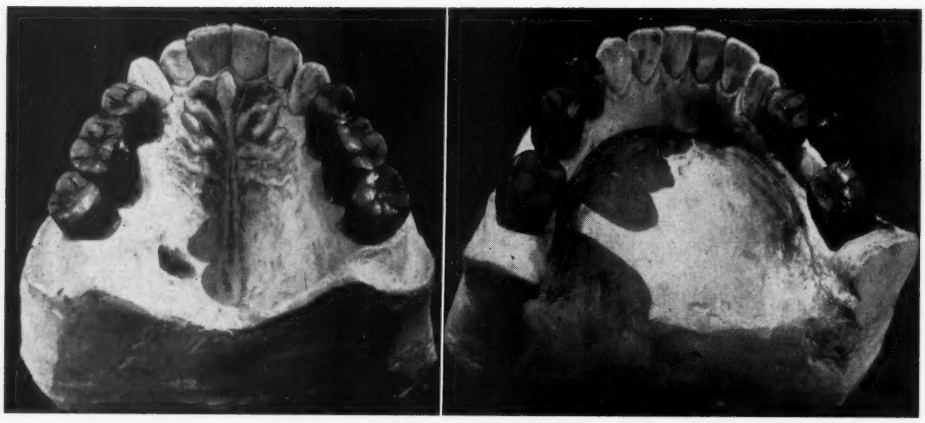

Fig. 3.—The dies are built up in wax to determine the buccolingual alignment and the plane of occlusion.

Fig. 4.—Skeleton frameworks are developed in the wax crowns of the opposing last molars. Note that the bulk of the wax of the occlusal surfaces has been removed.

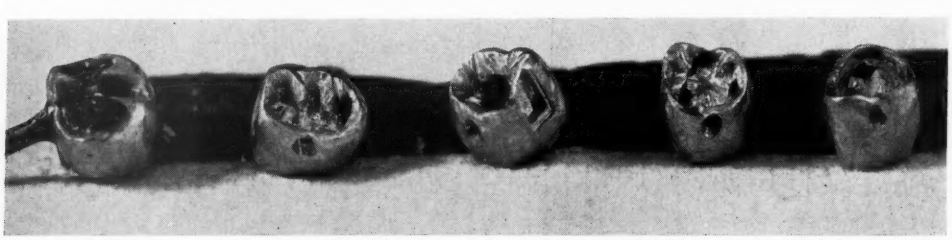

Fig. 5.—Gold skeleton crowns. Note the space on the occlusal surfaces made for the addition of wax. The wax chew-in has been developed on the crown on the left, the sprue is in place, and it is ready to invest. The new gold occlusal surface will be cast directly to the gold skeleton crown through the hole in the skeleton crown.

directly to the gold skeleton crown at a later stage. The wax skeleton crowns are removed from the dies, invested, cast in gold (Fig. 5), and are replaced on the dies. The spots where the wax was cut through to the die afford a means of determining if the gold skeleton crowns are properly seated.

GOLD SKELETON CROWN TRY-IN

The gold "skeleton crowns" are seated in the mouth, and the patient is instructed to close in centric relation to determine if the borders of the crowns touch simultaneously. Interfering contacts are determined by using articulating paper and are removed. When the patient closes every time in the same position, the correct centric relation has been obtained.

The patient then makes right and left lateral excursions, and the interfering spots are reduced until the anterior teeth come perfectly edge to edge. The procedure is repeated for protrusive excursions. Now there is harmony between jaw movement and tooth contacts irrespective of its nature.

The gold skeleton crowns are removed from the mouth, boiled in acid, and dried. The cavity on the occlusal surface of the crown is lined with a thin layer of wax containing borax,* and the remaining space is filled with inlay wax. The skeleton crowns are placed back into the mouth, and the patient is instructed to close in centric relation and move the jaw in the right and left lateral and protrusive excursions. These movements develop a chew-in in the wax occlusal surfaces. The crowns are removed from the mouth, and the final carving of the occlusal surfaces is completed.

CASTING THE OCCLUSAL SURFACES

Sprues are attached through the holes prepared for that purpose so as not to mar the occlusal carvings (Fig. 5). The crowns are reinvested, and gold is cast directly to the gold skeleton crowns. The investing rings must be hot (1,400° F. for 30 minutes for this procedure). The completed castings are replaced on the articulator, and if the error in occlusion is slight, it is necessary only to change the degree of inclination of the condylar guidances to make the articulator movements harmonize with the crowns. If more than this is required, a new wax interocclusal record is made with the castings in the mouth, and one of the casts is remounted (articulator adjustments are set at 0°) in centric relation according to the records obtained from the perfect articulator—the mouth. The articulator is adjusted for right and left lateral movements to correspond to the castings and the anterior teeth. The rest of the wax carvings are then corrected and cast, checked in the mouth, and finished and polished (Fig. 6).

SUMMARY

A procedure for creating a balanced occlusion with cast gold crowns has been described. The procedure has several advantages.

*Powers.

A.

B.

C.

D.

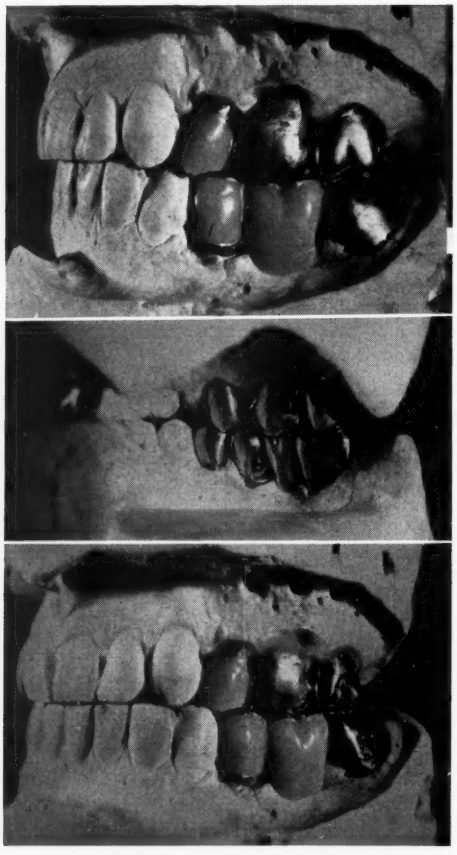

Fig. 6.—The completed castings are in place on the casts. Note that the posterior teeth have been restored to even contact when the anterior teeth are edge to edge.

1. When the gold skeleton crowns have been placed in the mouth and centric relation has been obtained, it is equivalent to having located the anatomic hinge axis of the mandible accurately. There is no fear that an error will develop when it is transferred to the articulator.

2. When the interfering spots on the gold skeleton crowns have been ground so the anterior teeth can come into edge to edge contact in right and left and forward mandibular positions, the dictates of the jaw movements have been carried out, and the precise degree of the vertical opening necessary has been established.

3. If there is a functional irregularity on one or both sides, the physiologic movement (including the Bennett movement) will have been accounted for because the data was obtained in the mouth which is the perfect articulator—the one no man can duplicate.

4. When the voids in the occlusal surfaces of the gold skeleton castings are filled with casting wax and chewed in, the small spines that jut into the voids permit the maintenance of the steepness of cusps and facilitate the final carvings of the occlusal surfaces when removed from the mouth.

When the gold occlusal surfaces are cast directly to the gold skeleton crowns, the crowns are completed, as is the problem of the increase of the vertical dimension of occlusion.

It is to be hoped that the simplicity of this method will be a stimulant for the practice of a much neglected phase of dentistry.

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FULL COVERAGE: THE PROVISIONAL AND FINAL RESTORATIONS MADE EASIER

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MULTIPLE FULL COVERAGE IN complex oral rehabilitation can pose problems in management which needlessly lengthen the time for the completion of the treatment plan. The fabrication of the interim crown and the grinding-in of the occlusion of the final restoration are both time-consuming procedures in which our techniques can be improved. This article concerns itself with two related techniques which make some progress in that direction.

PROVISIONAL OR TEMPORARY CROWNS

Aluminum and celluloid crown forms leave much to be desired as temporary restorations.[1] Their fabrication is time-consuming, and the esthetic result obtained is most unsatisfactory. When multiple restorations are made, their removal and replacement during intermittent operative visits usually result in a lessened accuracy of fit with each removal. The temporary crown fabricated of fast-curing acrylic resin, one which duplicates the shape and position of the patient's original tooth, usually is more comfortably worn by the patient, rarely is lost between visits, and can be easily removed and replaced during subsequent operative procedures. It can be easily and quickly fabricated during the same visit at which the tooth is prepared.

The local anesthetic is administered, and the interval before the advent of full anesthesia is used for the making of a simple baseplate wax interocclusal record-impression of the quadrant in which the tooth or teeth which are to be prepared are located (Fig. 1,*A*). At least two teeth on either side of the tooth which is to receive the crown are included in this record-impression. It is made with *no* intervening material between the upper and lower teeth. This permits us to fabricate a crown which is in the proper occlusion. The wax is softened, rolled into a cylinder of the appropriate length, and a side with no creases is placed on the occlusal surfaces of the quadrant in which the tooth is to be prepared. Then the wax is carefully molded by the fingers over the buccal and lingual surfaces of the teeth, and the patient is instructed to close in centric occlusion. The wax is molded also against the buccal surface of the teeth in the opposing quadrant. The patient is instructed to do the same with his tongue on the lingual surfaces (Fig 1,*B*).

Received for publication Oct. 17, 1957.
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The interocclusal record-impression is chilled in the mouth with a stream of cold water, and the patient is instructed to open while the wax is held in position on the quadrant to be prepared. The record is carefully teased from the teeth, using the fingernails on the border of the wax (Fig. 1,*C*). If the ball of the finger is used, the record-impression may be distorted by the pressure of the fingers. The first wax record-impression will be used in making the temporary crown. A second one is made in exactly the same way at this time (Fig. 1,*D*). The second interocclusal record-impression will be used for the construction of the master cast from which the final restorations will be made. Both record-impressions are inscribed with the patient's name on the buccal flange and laid aside for subsequent use.

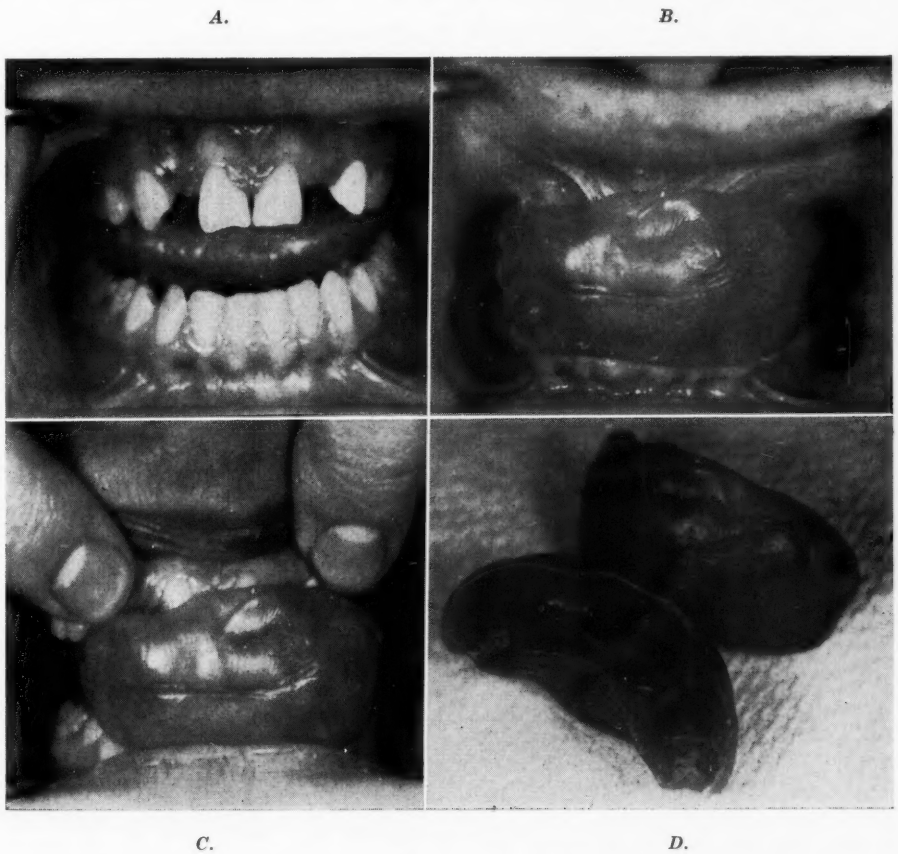


Fig. 1.—*A*, The upper left cuspid is to be prepared for full coverage. *B*, The baseplate wax interocclusal record-impression is molded by the fingers to the labial surfaces of the upper teeth before the tooth is prepared. *C*, The wax interocclusal record-impression is teased off the upper teeth, using fingernails at the mucobuccal border. *D*, The two wax interocclusal record-impressions are removed and filled for subsequent use.

By the time these record-impressions have been completed, the anesthesia will be effective, and the tooth can be prepared without loss of waiting time. The tooth should be prepared to the point where the preparation is nearly complete (Fig. 2,*A*). At this point, the fast-curing resin is prepared without stirring. It should have a

thick, creamy consistency and should be placed on the bracket table. The time necessary for the setting of the resin depends on the brand being used and the ratio of liquid to powder. When the surface of the resin has lost its sheen, when it becomes dull and the consistency is doughy, a suitable amount is placed in the interocclusal record-impression of the tooth being prepared and tamped into position with the butt end of the handle of an explorer (Fig. 2,*B*). Voids in the resin crown may occur if the doughy material is not tamped into position in the record-

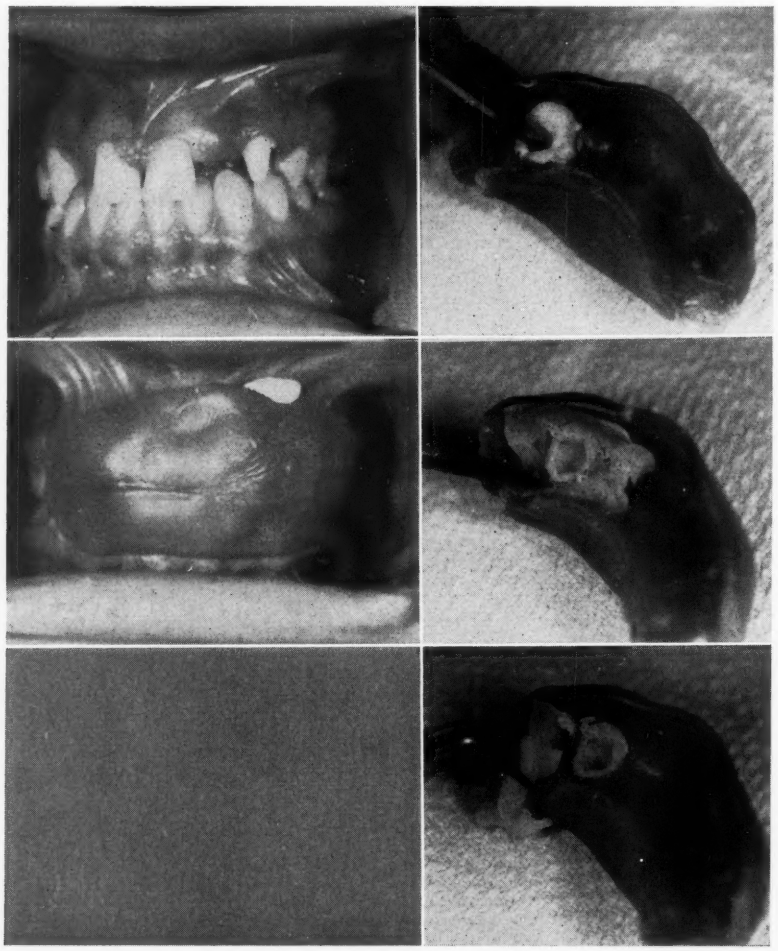


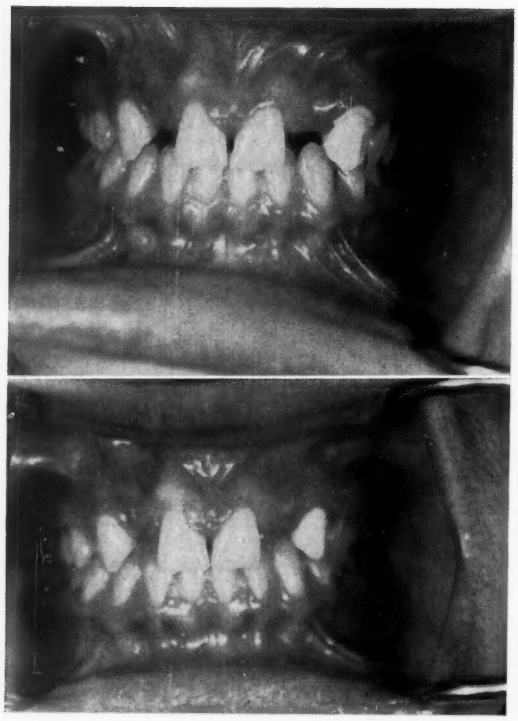
Fig. 2.—*A*, The preparation of the upper left cuspid is nearly completed. *B*, Self-curing resin of doughy consistency is pushed to the incisal edge of the wax interocclusal record-impression by means of the butt end of an explorer handle used as a plunger. *C*, The wax interocclusal record-impression with the resin in the impression of the tooth being prepared is seated in the mouth. The patient closes the teeth in centric occlusion. Note that the excess resin is squeezed over the mucobuccal flange of the record-impression. *D*, The outline of margins of preparation is scored by No. 11 Bard-Parker scalpel. *E*, The flash of excess resin is removed in one piece with cotton pliers.

impression. The wax interocclusal record-impression is then placed back in the mouth and positioned according to the unprepared teeth. The patient is instructed to close slowly and to "find" the same jaw position he had before (Fig. 2,*C*). The dentist can determine if the patient has closed properly by checking the opposite side. After a 30-second interval, the patient opens, and the record-impression is removed in the same manner as before. Then, with a sharp No. 11 Bard-Parker scalpel, the flash is scored to the outline of the margins of the finished crown (Fig. 2,*D*). Any flash or excess bulk which may have been driven into adjacent undercuts is removed with cotton pliers (Fig. 2,*E*). The record-impression is reseated, and the patient is instructed to close the jaw for the time required for the resin to set. This time is usually short, since most of the waiting time has elapsed with the material on the bracket table. The remainder of the "set" is hastened by the warmth of the mouth. The excess resin should be trimmed away in 30 seconds in order to prevent the escharosis of the gingival tissue which might result from prolonged contact with the resin. This possibility is minimized by using the resin in the doughy state since there is less free monomer in the resin at that time. If the resin is too soft, it will tear and pull on removal, and the setting time is increased. During attempts at synchronizing the preparation of the crown with the proper consistency of the resin, the resin may reach the proper doughy state while the preparation is several minutes from completion. The time required for completion of the preparation may allow the resin to set too hard for use. The resin should be used when it reaches its doughy consistency even if the preparation is incomplete. The resultant temporary crown will be loose on the tooth after the preparation is complete, but this void will be taken up by the zinc oxide and eugenol cementing medium. If the preparation is completed before the optimal consistency of the resin is achieved, the waiting time can be used for selection and contouring of the copper band for the impression. With the resin in an open Dappen dish, it can be observed and inserted in the record-impression at the proper time.

When the resin has hardened, the wax record-impression is removed from the teeth as carefully as before. This same wax record-impression may be used for the fabrication of a temporary crown for another tooth to be prepared at the next visit, or for the same tooth, if the temporary crown is lost. The rough crown will remain on the tooth when the wax is removed. The crown may then be removed with a crown remover which will catch on the slight gingival excess which usually remains at the buccal and lingual margins. Then the crown is trimmed with sandpaper disks, rubber wheels, and polished with pumice. It is cemented with a thin mix of fast-setting zinc oxide and eugenol (Fig. 3). The crown usually requires no occlusal or incisal adjustment since it was made under the natural occlusion of the patient with no intervening substance to keep the teeth apart. The excess of resin, which comes through any holes in the wax record-impression made by the contacting of the teeth, is easily removed during the trimming and polishing. Multiple crowns or temporary splints can be made by using the same technique (Fig. 4).

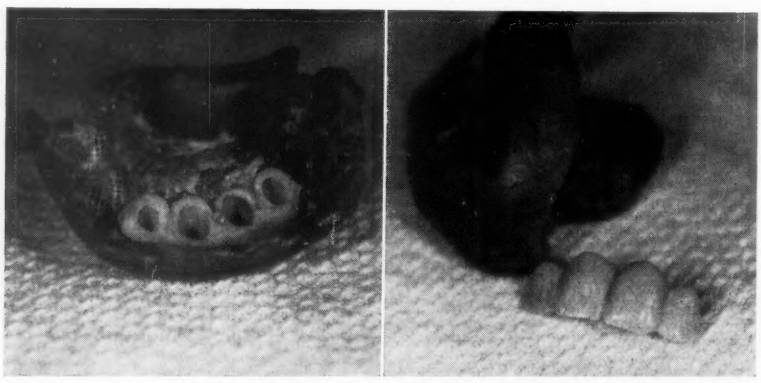
This technique can be used for making temporary crowns for any number of teeth being prepared in one jaw and has several advantages over the alginate matrix method.[2-4]

A.



B.

Fig. 3.—*A,* The resin has cured to hardness on the tooth at mouth temperature. The wax interocclusal record-impression is removed, and the crown remains on the tooth. *B,* The resin crown is finished and polished and cemented with a fast-setting zinc oxide and eugenol cement.



A. *B.*

Fig. 4.—*A,* A wax interocclusal record-impression for multiple restorations is made the same as for a single restoration. The doughy resin is trimmed 30 seconds after removal from the prepared teeth. *B,* A four-unit temporary acrylic resin splint has been polished and made ready for insertion.

1. Less time is required than for the selection of an alginate tray, mixing the alginate, and cleaning the bowl and instruments.

2. The cost of the materials is less.

3. The wax interocclusal record can be stored safely while the alginate impression cannot be stored for use at subsequent visits. A new alginate impression must be made for each tooth preparation.

4. A new resin crown can be made in the same record-impression whenever it is needed. Occasionally, a resin crown may be lost or broken between visits, even though this is less likely to occur than with other crown forms. With the alginate method, a hand-formed crown must be made to replace it since alginate cannot be stored.

5. With the wax record-impression, the resin hardens while the teeth are in occlusion and the occlusion is correctly established. Because an alginate impression is more accurate than wax, it is difficult to find the proper seat for it on the teeth when the resin is in the crown form. This may result in a crown which is too high, and time is needlessly spent grinding it into occlusion.

6. The resin crown made in the wax record-impression has greater gingival bulk which stands up better on subsequent removals and replacements of the crown. The wax is slightly distorted as it is withdrawn over the bulge of the buccal and lingual surfaces of the teeth. This results in stronger margins on the crowns than those made with alginate impressions. The reduction of the tooth at the gingival margin is considerably less than at other portions of the tooth, so a resin crown made in an alginate form will have fragile gingival margins.

7. With the wax record-impression method, the same record-impression can be used for both crowns, which are used for nonvital teeth being prepared for gold post and porcelain or acrylic resin veneer crowns. One temporary crown with the post attached is needed before the gold post is made and another crown is needed after the gold post has been cemented. With alginate, a new impression is needed for each.

THE FINAL RESTORATION

Two wax interocclusal record impressions were made before the tooth was prepared. The first of these was used for the fabrication of the temporary restoration. The second one is used in making the permanent restoration. The accuracy of the contact point and occlusion of the final crown is dependent on the positioning of the die in the impression and the relation of it to the opposing teeth.

In the usual technique for making porcelain jacket crowns, an impression of the operative quadrant is made in plaster of Paris, and the die is seated in this rigid impression to insure greater accuracy than can be achieved with a wax impression. Using the plaster impression alone for seating the die often results in an inaccurate master cast, hence, transfer copings are used by some to overcome this difficulty.[5,6] The second wax interocclusal record-impression is used in a practical and simple technique for achieving comparable results to that obtained with transfer copings.

After the tooth has been prepared and the copper band and compound impression is made, a mix of zinc oxide and eugenol impression paste is made (Fig. 5).

A quantity of this paste sufficient to fill just the impression of the prepared tooth is placed in the wax record-impression (Fig. 5). This is then reseated on the operative quadrant, and the patient is instructed to close the teeth into the record as described previously. The paste sets in a few minutes in the warmth and humidity of the closed mouth. The wax record is then carefully removed as before,

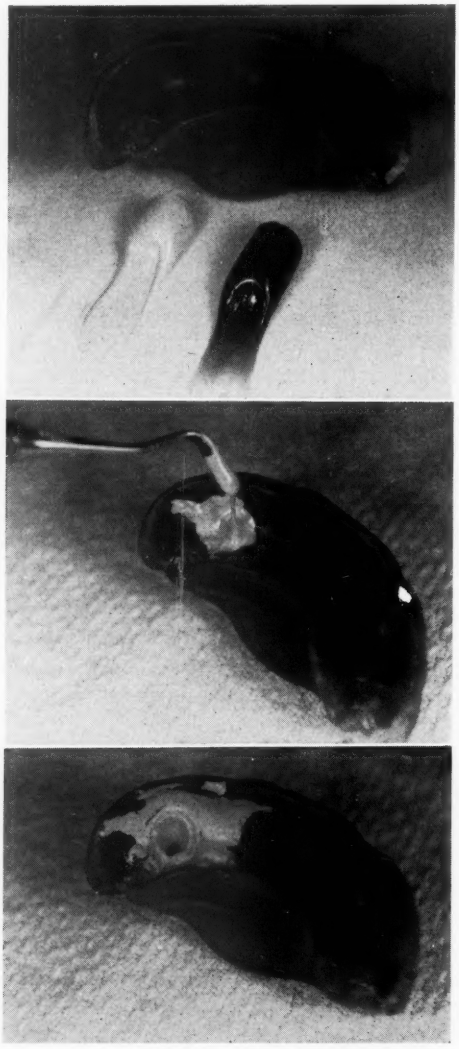


Fig. 5.—*A*, A zinc oxide and eugenol paste is measured for mixing and placement in the impression. *B*, The paste is inserted into the wax interocclusal record-impression of the prepared tooth only. *C*, The paste-impression shows the sharp outlines of the preparation.

and the zinc oxide and eugenol lining is examined for detail. The impression of the prepared tooth will usually show a very sharp outline of the preparation, and even the impression of the gingival crevice will be clearly defined (Fig. 5). Using

too little of the paste will result in an incomplete impression of the preparation. Using a quantity in excess of that required to fill up the tooth impression may cause the entrapment of the hardened paste in the undercuts of the adjacent teeth, and the paste will remain around the teeth rather than come out with the wax record-impression.

The counter cast and a projecting index are poured into the opposite impression of the interocclusal record. The accurately trimmed die is then positioned in the paste impression in the wax record-impression and luted with wax (Fig. 6). After the notched index of the counter cast has been treated with a separating medium, the master cast is poured into the wax record-impression and against the stone index. The casts are separated in warm water and are ready for use in waxing (Fig. 7), or for the fabrication of crowns.

Fig. 6.

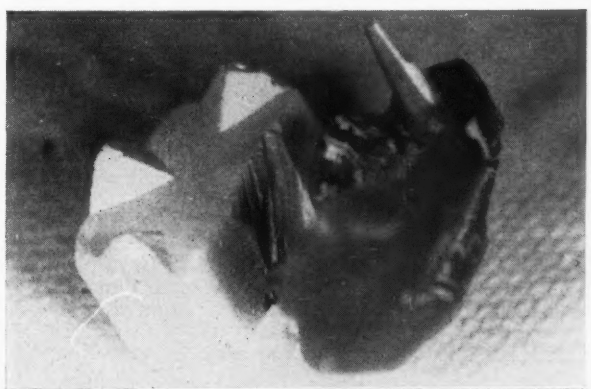


Fig. 7.

Fig. 6.—The counter cast and stone index. The die has been placed in the paste-impression within the wax interocclusal record-impression.

Fig. 7.—The master cast with the dies in position after the paste-lined wax interocclusal record-impression has been removed by softening it in warm water.

This technique offers the advantage of simplicity and results in a cast which, if carefully made, permits the construction of a crown with little or no adjustment of the contact points or occlusion. The sharpness of the outline of the margins of the preparation which can be seen in the zinc oxide and eugenol paste permits seating the die accurately in its proper position.

For individual quadrants, the use of casts with a notched index is advocated rather than the small sectional articulator which is often responsible for errors because of the inaccuracy of the instrument. The insertion of a previously made cast into a wax interocclusal record to obtain a record of the opposing occlusal surfaces is often a source of error in the occlusion of the finished crown. This possibility is eliminated when both master and counter casts are made from a single interocclusal record.

SUMMARY

A method for making single or multiple temporary crowns of fast-curing autopolymerizing acrylic resin has been described. Synchronization of the procedures used at the chair and the utilization of the setting time of materials for other operations enables more to be accomplished in a given time and, thereby, it reduces the number of visits for the completion of treatment.

The construction of an accurate master cast which minimizes time spent in adjusting occlusion and contact points of the finished restorations has been described. The possibility of eliminating transfer copings and time-consuming plaster impressions without loss of accuracy can result in a reduction in the number of patient visits and a saving of valuable chair time.

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FURTHER INVESTIGATIONS INTO THE NATURE OF HYGROSCOPIC EXPANSION OF DENTAL CASTING INVESTMENTS

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Since the introduction of hygroscopic investments to dentistry, several investigators have performed rather concentrated research on the various physical characteristics of this phenomenon. Others have tried to explain the mechanism of such an expansion.

Skinner and Degni[1] proposed that precipitating gypsum forms a colloidal gel which imbibes water and expands. Lyon, Dickson, and Schoonover[2] proposed that hygroscopic expansion is a continuation of the normal setting expansion which is permitted by the weakening of the mass by the silica and is caused by the further hydration of the crystals by the added water. Ryge and Fairhurst[3] have proposed that the surface water is absorbed by capillary action into the minute interstices as they are formed, and water films force the particles apart.

Each of these theories has some merits, but none of them, as presented, accounts for all of the variations reported when alterations are made in manipulative procedures. An acceptable theory should be one which is derived not only from basic research, but one which also explains the effects of different manipulative conditions. Although much is known about hygroscopic investments and their behavior, still there are characteristics which are undetermined.

In this report, an attempt is made to study two more phases of hygroscopic expansion. First, a method for measuring the internal or effective expansion of the cavity in the investment is described. Second, the effect of varying the silica content in the investment is presented. The latter has been partially determined by both Docking[4] and Degni[1] but neither of them studied investments containing more than 90 per cent silica, and neither investigated the effects of controlling the amount of water added to the investments.[5] In this work, special emphasis was placed on investments containing more than 90 per cent silica.

EXPANSION OF CAVITY

One problem related to measuring by hygroscopic expansion is that linear measurements normally are made on the exterior of the investment mold, whereas

This study was supported by a contract between the Office of Naval Research, Department of the Navy, and the University of Michigan (NR 180-360).

Read before the International Association for Dental Research in St. Louis, Mo., March 24, 1956.

Received for publication May 17, 1956; revised by the authors March 12, 1958.

*Physical Research Laboratory.

it is the expansion of the cavity that is important to the casting technique. The cavity expansion apparatus was built to determine the internal cavity expansion (Fig. 1).*

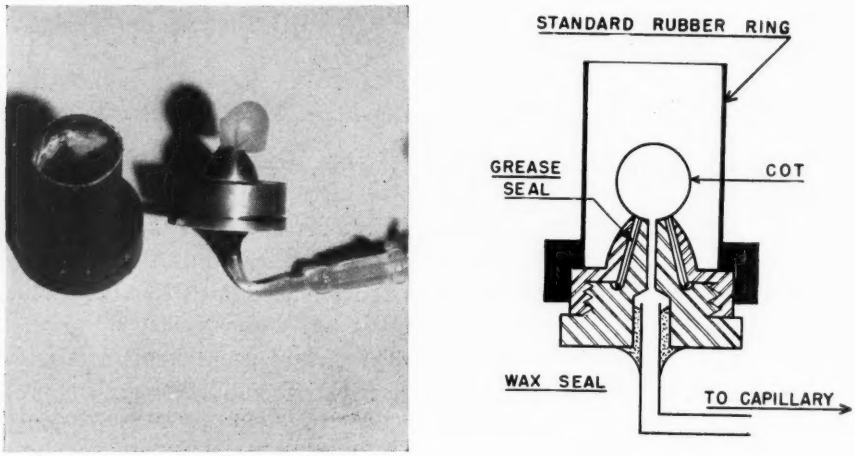

Fig. 1.—A schematic drawing and photograph of the elements of the cavity expansion apparatus for measuring the expansion within the cavity.

The apparatus consists basically of a small rubber cot which is held between two closely fitting pieces of brass, and a seal is maintained with grease. The cot is adjusted so that the extended portion will enclose a volume slightly greater than 1 c.c. of liquid. A small hole in the lower piece of brass allows the cot to be filled with water. A glass tube is attached to the brass holder with soft utility wax, and a capillary tube is fitted to a joint at the end of the tube. Thus, when filled with water, any change in the volume enclosed by the cot is accompanied by a corresponding change in volume in the capillary tube. In Fig. 2, the instrument is shown in use. A calibration of the tube showed that a deflection of 1 mm. in the length of the water column in the tube corresponded to a change in volume of 0.000785 c.c. in the cavity. The volumetric expansion in per cent is simply 0.0785 times the number of millimeters that the water column changed, divided by the measured volume of the cavity. Since the volume of the cot was 1.25 c.c., it was possible to detect a change in volume of 0.06 per cent, which represents a change in linear dimension of 0.02 per cent.

In use, the cot and capillary tube were filled with water, and the investment was mixed. A small amount of investment was painted around the cot to exclude air, and the external standard rubber ring was put in position and filled with investment. Water could then be added to the surface in any controlled amount. The method used then was essentially the water added technique for preparing hygroscopic investments.[5] As the reaction took place, readings were taken from

*A similar apparatus was used in Brazil by L. W. Suffert[6] in connection with the effect of asbestos liner on the setting expansion of the investment.

the capillary tube at one-minute intervals. When the reaction was complete (45 minutes from the start of mix), the volume of the cavity was measured by determining the amount of water needed to fill the cavity.

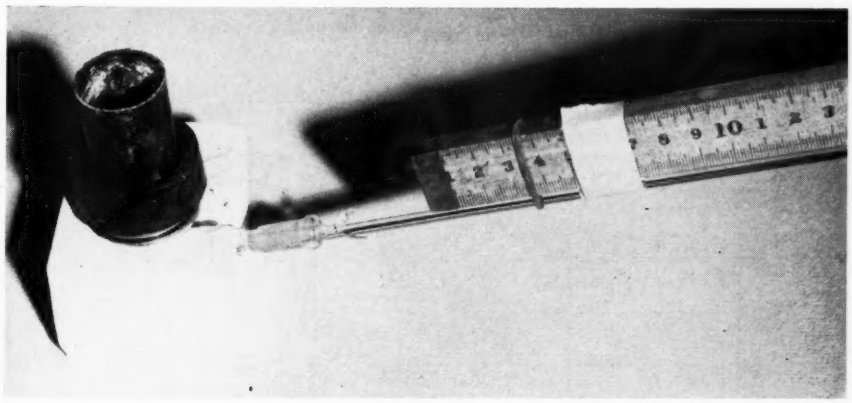

Fig. 2.—The apparatus set up for use. Measurement of change in length in the water column was done with a meter stick.

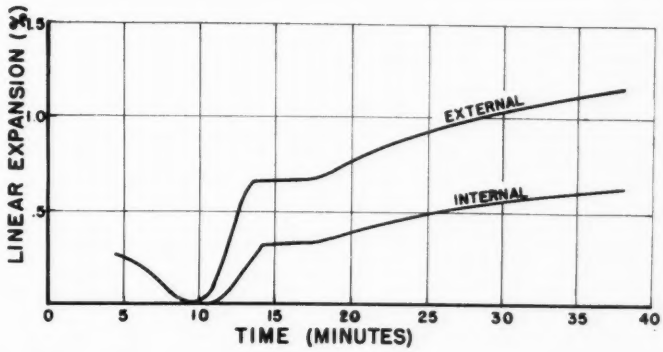

Fig. 3.—Comparative tests, water added 0.5 c.c. The internal and expansion curves for one investment. The loss of gloss occurred at 10 minutes, and the Gilmore needle initial set at 20 minutes.

The results of comparative tests were plotted and are shown in Fig. 3. A commercial hygroscopic investment* was mixed according to directions and divided into two parts. One-half was used to determine the external expansion, determined by the method previously employed,[5] and the other to determine the internal expansion. To each, 0.5 c.c. of water was added. A small amount of investment was retained to determine the loss of gloss and initial setting time. It can be seen that the external expansion started earlier and at all times was greater than the internal expansion. The time at which the investment started to expand

*Aqua-Pak, Ransom and Randolph Company, Toledo, Ohio.

externally was very close to the time for the loss of gloss. The internal expansion started one or two minutes after the external expansion. When the surface water was absorbed, the material ceased to expand for a period of 4 or 5 minutes, as can be seen from Fig. 3, and then near the initial set time, it proceeded to expand, but at a much slower rate than initially.

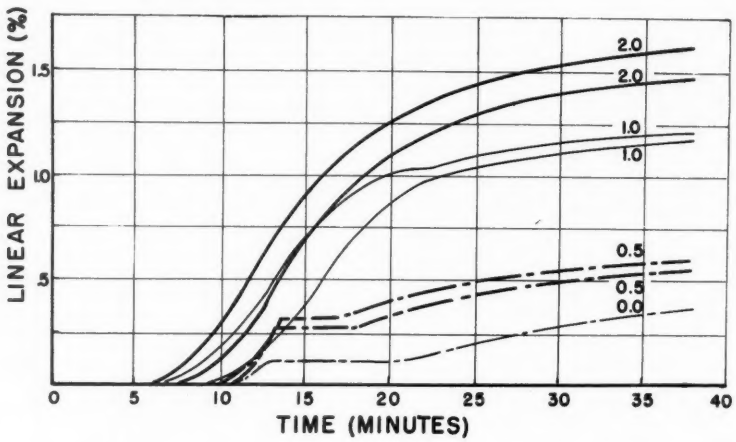

Fig. 4.—Cavity expansion, water added as shown. The effect of varying the amount of added water.

The effect on the internal expansion when the amount of added water was altered is shown in Fig. 4. For these tests, 0.0 c.c., 0.5 c.c., 1.0 c.c., and 2.0 c.c. of water were added, and internal expansion of the investment was measured using the same Ransom and Randolph Aqua-Pak. Ten tests were run for each of the four conditions just mentioned above. When no water was added, practically all the runs resulted in the same internal expansion. As the amount of added water increased, the variation between the runs also increased. In Fig. 4, the maximum deviation between the runs for 0.5 c.c., 1.0 c.c., and 2.0 c.c. water added also is shown by the two curves for each condition. It was observed that the results were much less consistent when the investment was saturated with water. This tends to substantiate the principle that a controlled amount of water added will produce a consistent controlled amount of expansion. When no water was added, the investment absorbed the normally small amount of water that always exists on the surface of the mix, causing the gloss that is characteristically observed. This resulted in 0.1 per cent linear expansion between 15 and 20 minutes, with no additional water added. Generally, the initial rate of expansion, as shown in Figs. 3 and 4, was found to be about 0.3 per cent per minute, while the secondary expansion rate was about 0.03 per cent per minute.

EFFECT OF SILICA CONTENT

In order to investigate the effect of silica content in the investment, a series of investments containing varying proportions of silica and hydrocal were pre-

pared. The silica size was 200 mesh and contained less than 0.03 per cent impurities. The components were weighed on a dietetic scale, unless there was less than 5 per cent of a component in the mixture, in which case, an analytical balance was used. Each investment was mixed for a minimum of 4 hours on a ball mill. The water to powder ratio was determined for each investment in accordance with A.D.A. Specification No. 2, Section F-2, for the slump test of an investment. The mixtures and the corresponding water-powder ratios are given in Table I.

TABLE I. COMPOSITION OF INVESTMENTS

PER CENT SILICA	PER CENT HYDROCAL	WATER-POWDER RATIO
0	100	.350
25	75	.340
45	55	.330
65	35	.325
80	20	.315
90	10	.310
95	5	.310
96	4	.310
97	3	.310
98	2	.310
99	1	.310
100	0	.310

The external expansion of each sample was measured by the method described by Asgarzadeh, Mahler, and Peyton.[5] For each test, the amount of the investment to be used was weighed and mixed with a measured amount of water. Each sample was spatulated 100 turns in a hand mechanical spatulator. The investment was poured into a standard rubber ring and vibrated. A small wire was placed on the surface, and water was added from a syringe. The vertical movement of the wire was measured with a cathetometer, as shown in Fig. 5. After 45 minutes, the length of investment was measured with a micrometer, and the percentage of expansion was calculated.

The relationship between the silica content and the total external expansion for different amounts of added water is shown in Fig. 6. When the surface remained saturated, the expansion increased rapidly as the silica content approached 95 per cent of the investment. (Mathematical treatment will show that the curve is an exponential.) Above 97 per cent, the curve dropped steadily, and at 100 per cent, no expansion or reaction of any kind was visible.

When 1.0 c.c. of water was added, the investment was saturated if it contained less than 60 per cent silica. The expansion curve for the 1.0 c.c. and the saturated condition coincide within this range. If the investment contained more than 60 per cent silica, the expansion remained constant as the proportions of the silica and hydrocal were varied when 1.0 c.c. of water was added.

The lower curve in Fig. 6 represents the normal setting expansion of the various investments. Up to 80 per cent silica, the expansion increased slightly as the ratio of silica to hydrocal was increased. With 90 per cent silica no expansion was observed, and with 95 per cent silica the investment mass contracted slightly.

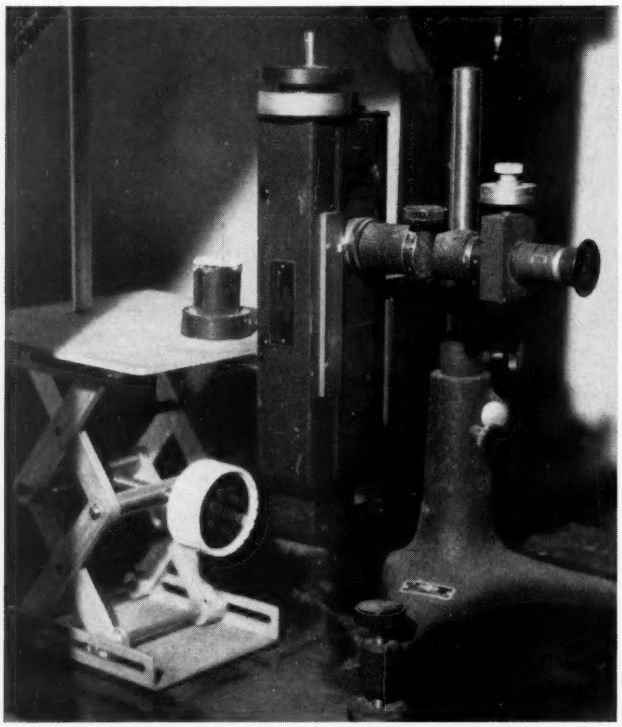

Fig. 5.—The cathetometer used to measure the movement of a wire on the upper external surface of the investment.

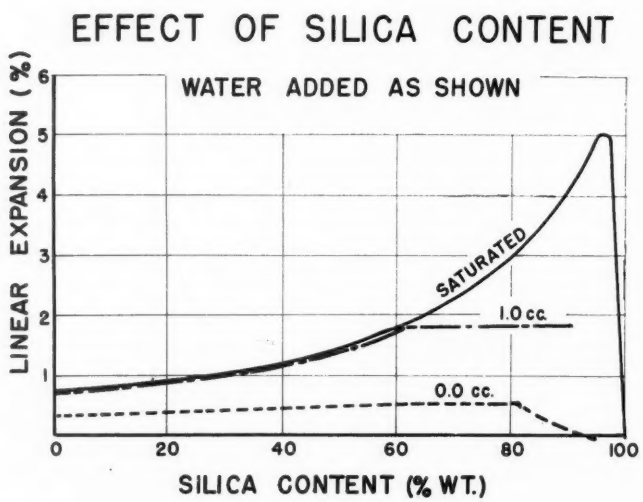

Fig. 6.—Effect of silica content. The relationships of silica content and water added to the expansion.

It was observed that these last two investments started to expand just before the loss of gloss, and then slowly contracted to their final values. A sample of mixed investment and water containing 95 per cent silica was prepared and allowed to stand overnight at room conditions. When water was then added to the surface to produce a temporarily saturated condition, it expanded hygroscopically. The initial water added after 20 hours' standing was absorbed rapidly, and further water was added at the times shown in Fig. 7. The investment mass developed a total of 8 per cent linear expansion before it was allowed to dry in air for 68 hours and then was resaturated. The investment then expanded 16.8 per cent linearly, which appeared only in the vertical direction. Measurements indicated no lateral expansion to exist.

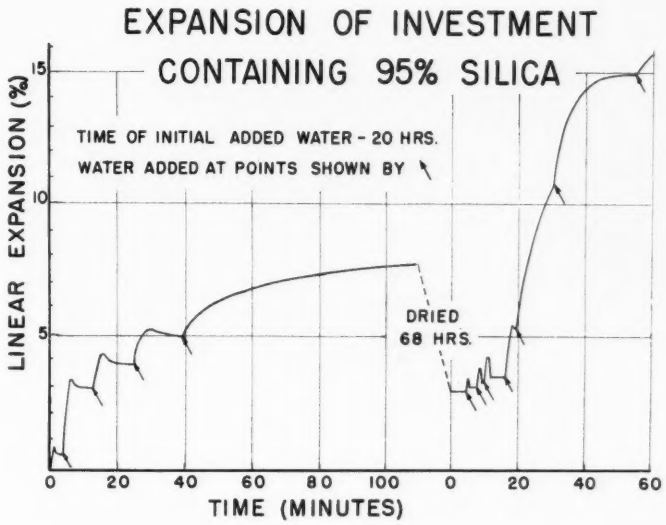

Fig. 7.—The expansion time curve of an investment containing 95 per cent silica. Similar results were observed for dry pure silica.

The expansion observed could not have been caused by further hydration of the gypsum, since only 5 per cent of the investment was hydrocal which had been saturated for at least 5 hours, and the investment had contained water for perhaps 90 hours. Therefore, to study the behavior of the silica ingredient, a sample of pure silica was mixed with a water-powder ratio of 0.310, placed in the mold, and allowed to dry. After 20 hours, water was added to the surface, and the pure silica expanded approximately 8 per cent. Further tests showed that, if the silica samples were thoroughly dried, the maximum expansion was in excess of 20 per cent linearly. The investment containing 95 per cent silica showed a maximum expansion of 21.5 per cent, while pure silica expanded 20.7 per cent, which is considered equal, with the difference being experimental error.

Certain characteristics of the expansion of pure silica were noted. Unlike the expansion of a normal investment, this expansion could be repeated after the

silica mass was dried. The expansion took place locally, because there was an immediate expansion when water was added, followed by a small gradual contraction after the water was absorbed into the mass. There were small air bubbles incorporated in the mass, which could escape only if the silica was agitated. The expansion did not depend on the method in which water was added. That is, water could be added 1 c.c. at a time, or 10 c.c. initially, and the over-all expansion was essentially the same. Finally, it was observed that this expansion occurred in the vertical direction only, while normal investments expand in all three dimensions.

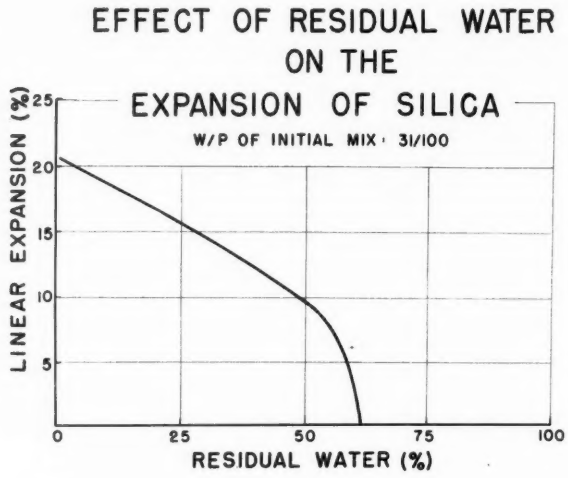

Fig. 8.—The effect of residual water on the expansion of pure silica. The critical point occurs when 58 per cent of the original water remains.

Pure silica will expand only under a specific set of conditions. The silica must be mixed with water and allowed to settle. It must then be dried until air is incorporated into the mass, and the air must be present at the time the water is added to the surface. The last statement was proved when water was added to a completely dry sample of silica in a vacuum, and no expansion occurred. Moreover, the expansion depends on the degree of dryness, or conversely, the amount of residual water in the sample. Density measurements indicate that about 42 per cent of the volume of a sample is air or water and 58 per cent of the volume is silica. During the drying process, both air and water will be present in the sample, and it might be expected that the expansion would vary with the amount of residual water. Samples were prepared and weighed on an analytical balance and allowed to dry in air. At various stages in the drying process, samples were weighed again and expanded immediately. In Fig. 8 is shown the relationship between the expansion and the per cent of residual water in the silica mass. Until a critical value was reached at about 58 per cent residual water, the material did not expand. When the water content went below this point, a large expansion was measured.

PRESENCE OF AIR OR VOIDS

Two additional experiments were carried out in order to clarify some conclusions that might be drawn from the results above. To determine whether parts of the silica remained dry even during spatulation, the components for an investment containing 65 per cent silica were weighed, and the correct amount of water was measured. The silica alone was mixed with the water and allowed to stand covered to prevent evaporation of the water for 20 hours. In this manner, all the surfaces of silica were completely wet. The hydrocal was added to the water-silica mixture and spatulated, and the external expansion was measured with excess water added to saturation to the surface. It expanded 2.1 per cent, compared to 2.2 per cent for a similar investment treated in the ordinary way. In order to determine whether air was incorporated during spatulation, an investment was prepared in vacuum and then allowed to expand. The expansion was approximately the same as when it was treated in the conventional manner. From these tests, it appears that the silica is wet in a normal investment, and that any air that is incorporated during spatulation has a negligible effect on the hygroscopic expansion.

There is only one other possibility for voids, interstices, or dry spots to occur in the investment. As the reaction between the hydrocal and water takes place, the volume is decreased.[7] If water could not get to the point at which the reaction occurred, a void would be formed. Reference to the theories of fluid flow[8] and vapor pressure[9] shows that the vapor pressure in such a void will be about 20 mm. of mercury at room temperature, whereas the normal pressure on the exterior of the investment would be 760 mm. of mercury. The pressure difference amounts to 740 mm. of mercury, or 14.3 pounds per square inch. A void will not form until this pressure differential is formed, and it can be formed only if the viscosity forces are sufficient to cause this pressure differential.

On the assumption that the particles in the investment do not move significantly and that the flow rate of water through the investment is directly proportional to the pressure differential, a test was devised to determine the effect of the viscosity forces. A sample of a normal investment, 29 mm. in diameter and 12 mm. thick, was sealed in wax, as shown in Fig. 9. The sample approximated the average volume through which water must travel in an investment held in a standard rubber ring. The upper surface was exposed to atmospheric pressure, while the lower surface was maintained at a reduced pressure of approximately 1 pound per square inch with a Hollenback type vacuum investing machine. A pressure differential of 14 pounds per square inch was maintained across the sample. Under these conditions, 1.5 c.c. of water per minute flowed through the sample. The maximum flow rate in a normal investment was found to be approximately 0.15 c.c. per minute. This indicates that the maximum pressure differential between the interior and exterior of an investment is in the order of 1.4 pounds per square inch, which is insufficient to allow the formation of a void at any time when there is free surface water.

DISCUSSION

There are several implications to be derived from the data presented. Hygroscopic expansion is actually two distinct expansions, which occur at different times and with different rates, as was shown in Fig. 3. The first expansion results from the absorption of water, starting just prior to the loss of gloss and ceasing when the surface water is absorbed. The second expansion is much slower and is more or less independent of whether water was added to the surface. It seems probable, therefore, that this is caused by the growth of crystals in the investment and may, therefore, be referred to as a part of the normal setting expansion of the investment. The first expansion appears to be the true hygroscopic expansion. Whenever the investment is saturated, the two expansions will overlap, giving a continuously changing expansion rate curve.

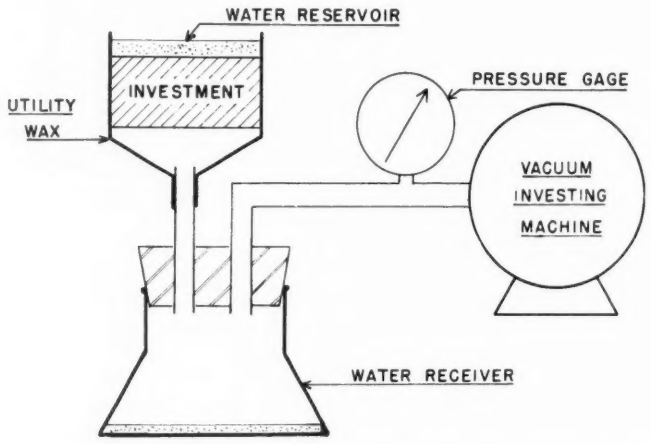

Fig. 9.—A schematic drawing of the flow rate apparatus, not drawn to scale, used to determine the effect of the viscosity forces. The pressure in the receiver was maintained at approximately 14 pounds per square inch below atmospheric pressure.

Since the first hygroscopic expansion takes place between the loss of gloss time and the initial set time, as shown by the Gilmore needle, the investment is rather weak and offers little resistance to expansion. Moreover, investments containing more than 80 per cent silica do not harden, and yet they show the greatest total expansion. This infers that hygroscopic expansion is not primarily dependent upon the crystal growth of calcium sulfate with silica serving to weaken the mass.

From Fig. 6 it was noted that the maximum expansion was measured with 94 per cent to 97 per cent silica, or 3 per cent to 6 per cent hydrocal. This is relatively a small amount of hydrocal, and it would seem improbable that the resulting crystals would yield such a high expansion. Furthermore, an investment containing 95 per cent silica will expand even when the water is added 20 hours *after* mixing. This is not a phenomenon that is associated with normal crystal growth. Thus, it would appear that, while the second expansion may be a manifestation of crystal growth, the first expansion is not and is possibly a physical phenomenon.

It was also shown that it is highly improbable that any voids or interstices are formed as long as there is any free water present on the surface of the investment. Also, the forces of capillary action are tangential to the surface, and where all surfaces are wet, all tangential forces are in equilibrium, even though adhesive forces may be present. In a normal investment, all adhesive forces also form a state in normal equilibrium, since surface water is not absorbed until the chemical reaction takes place. Thus, since it was shown above that all particle surfaces are wet, that all surface forces are in equilibrium, and that no dry surfaces are formed, the water does not flow by capillary action. Rather, the influx of water is merely due to a continuous transfer system where water flows from the exterior surface to the point where it is needed in the interior. However, a particular water molecule which is added to the top of the ring does not necessarily penetrate all the way to the bottom of the ring where the water is needed. Since the investment mass is always mixed with an excess amount of water, a point on the bottom of the ring which needs extra water can easily absorb that amount of water from the excess water which is adjacent to that point. Likewise, the next point can satisfy its water need by absorbing some water from another point adjacent to it. In this way, the added water molecules do not have to travel all the way to the bottom of the ring; they may penetrate only a few millimeters. Moreover, if all surfaces are wet, there are films of water around each particle at the end of spatulation, and no new films are formed during the reaction, even though the film thickness might change. It was pointed out above, in the description of the test on pure, completely dry silica with water added in a vacuum, that no measurable expansion took place. Yet, this is a situation in which films are formed between particles. Thus, it appears highly doubtful that any new films are formed between particles, or that they could cause hygroscopic expansion, if they were formed.

Perhaps it should be noted that just because pure silica can be made to expand, it does not necessarily prove that hygroscopic expansion and the expansion of pure silica are the same phenomenon. Several characteristics of pure silica are listed, and they are considerably different from the characteristics of a normal hygroscopic investment. There may be a connection between the two, however, in that they show very similar initial and final characteristics. Further study is being given to this phase of the problem.

CONCLUSIONS

1. The cavity starts to expand at the time that the loss of gloss is observed. Using Ransom and Randolph Aqua-Pak investment with 1.0 c.c. water added, the internal expansion is approximately 1.2 per cent, whereas the external expansion is 2.0 per cent linearly.

2. Expansion takes place in a hygroscopic investment in two separate and distinct steps which may overlap if sufficient water is present.

3. Pure silica can be made to show an expansion similar to the expansion observed in a hygroscopic investment, although the mechanism of each perhaps is different.

4. Results indicate that hygroscopic expansion is not caused by a continuation of the normal crystal growth, nor is it caused by water being drawn into voids or interstices by capillary action, although a portion of expansion may be due to crystal growth.

5. Any theory will have to take into account the fact that the maximum expansion takes place in an investment containing only 3 per cent to 6 per cent of hydrocal.

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RESEARCH

CHANGES IN THE TRABECULAR PATTERN OF THE MANDIBLE FOLLOWING THE LOSS OF TEETH

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THE HUMAN MANDIBLE IS subject to radical changes when teeth are lost. These changes are in its gross form and in its internal structure, and they affect the efficiency of prosthetic restorations.

From a purely anatomic standpoint, the human mandible is of particular interest because it shows innumerable variations, not only during the periods of growth but also in the course of the entire life of an individual, and is subject to drastic changes in morphology.

All osteologic problems, whether of histologic or morphologic or mechanical nature, are apparent in the mandible and suggest interesting fields of research to investigators.

Bone is not the fixed and permanent structure which its relatively dense composition might seem to indicate. The abilities of bone to bend, resist torsion, compression, and tensile stresses depend on its fine macroscopic and microscopic structure. It performs dual functions in the body by providing both a mechanical protection, support, and leverage as well as the biologic functions of acting as a calcium and phosphorus reservoir in the body, and as a site for blood-cell formation.

Macroscopically, every bone has a superficial layer of compact bone of varying thickness. Beneath the covering of compact bone is a spongy or netlike structure of bony plates called cancellous bone. This cancellous bone is most abundant in the extremities of the long bones (as the femur) and in the interior of short and flat irregular bones (as the vertebrae, mandible, and carpal bones).

Bone is one of the most labile tissues of the body, and one in which every change of tissue metabolism, diet, and function is recorded. The internal and external architecture of bone changes constantly throughout life. The remodeling which occurs offers evidence of its ability to accommodate itself to the work placed upon it.

The plastic quality of bone is evident throughout the life of an individual, and it is this inherent plastic nature of bone, its ability to change its form and to respond

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Condensed from a thesis presented in partial fulfillment of the requirements for the degree Master of Science at The Ohio State University, College of Dentistry, Columbus, Ohio.
Received for publication March 15, 1957; revised by the author Sept. 23, 1957.

to its environment, that is responsible for the intimate relationship between form and function.

A review of the literature made it evident that this problem has received considerable attention for many years by numerous investigators. Previous research seems to indicate that there is a change in the trabecular pattern in the mandible due to the loss of teeth. However, in the literature reviewed preparatory to this study, no detailed description was found of the rearrangement of the trabecular pattern which takes place in the mandible following the loss of teeth.

The objectives of this study were to determine the nature of the changes of the trabecular pattern within the mandible and to attempt to find a means for studying the causes of the individual variations in the changes that are known to occur.

MATERIALS AND METHODS

One hundred and fifty human mandibles were used in this study. The dried specimens were obtained from the anatomy department of The Ohio State University, and all were removed previously from cadaver material. Gross observations of 65 other mandibles were made and used in the over-all survey of bony structure.

Three main techniques of study of the structures of the trabecular pattern of the dried mandibles were used: (1) ground sections, (2) decalcified specimens cut into serial sections, and (3) roentgenograms.

Four mandibles from full-term stillborn babies and one mandible from a child approximately 7 years of age were also included in the study for the purpose of comparison with the adult specimens.

Roentgenograms were made of dentulous and edentulous dry specimens. Occlusal and regular intraoral dental films were used in some areas in patients to show the fine detail of the trabecular patterns in the living state.

DISCUSSION AND RESULTS

The cancellous bone in the mandible is continuous with the inner surface of the surrounding cortical bone and exists as a three-dimensional latticework of trabeculae. The spaces between this latticework are compartmented red-marrow cavities and vary greatly in size and number in different individuals. This variation in the trabecular pattern is clearly seen in the illustration and roentgenograms of many of the mandibles studied (Fig. 1).

Forces which are applied to the mandible by the muscles of mastication in their various actions cannot be observed directly in the living specimen. Therefore, only the reaction of the bone in the change of its structure can be studied in dry specimens. To counterbalance such forces, two factors in the development of the bone are involved. These are the arrangements of the molecules of the bony substance in a direction parallel to the direction of the forces and the modification of the gross structure in such a way that it is best able to withstand the forces. This is shown by the directions of the trajectories.

The mandible of a full-term fetus is made up of two nearly horizontal troughs of bone joined at the midline or symphysis by fibrous tissue. The body of the bone

is partially developed, and it is proportionately shorter than in the adult. It is largely hollowed which provides space for the developing teeth, and practically no trabeculation exists. The rami are short, so much so that the condyles are almost on the same plane with the superior border of the body of the mandible. The mental foramina are nearer to the lower border of the mandible than to the upper border (Fig. 2). Roentgenograms of these fetal mandibles showed clearly the relationships of the developing teeth to one another and to the upper and lower borders of the body of the mandible.

Fig. 1.

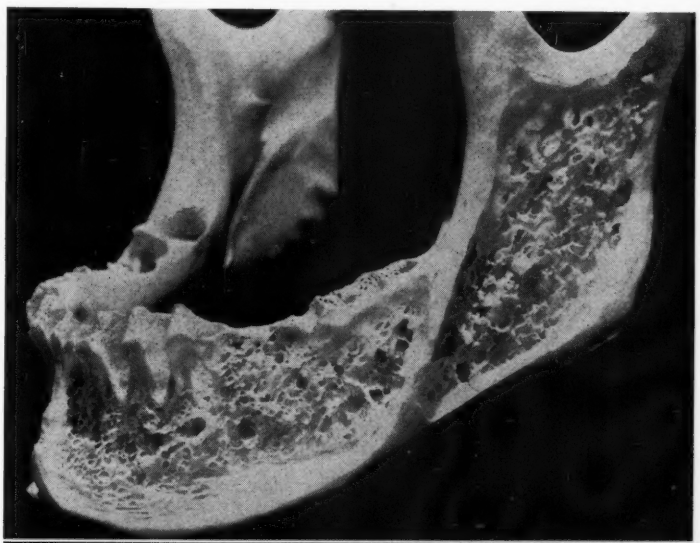

Fig. 2.

Fig. 1.—The pattern of the trabeculae in an adult dentulous mandible. The specimen was dissected to show the relation of the cortical plates to the trabeculation.

Fig. 2.—The mandible of a full-term fetus showing a trough along the superior border of the alveolar process. The developing teeth have been removed.

In a section of a mandible of a child of approximately 7 years of age, the crowns of the permanent teeth are situated below and lingual to the roots of the deciduous teeth. The crowns of these partially formed teeth are situated in close proximity to the inferior dental canal and to the lower border of the mandible at this stage of their development (Fig. 3). The trabeculae are arranged horizontally between

adjacent teeth, as well as between the alveoli and the surrounding cortical bone. The trajectories, thus formed, correspond with the forces exerted upon the teeth. The pattern of the trabeculation in the ramus is somewhat similar to that of the adult mandible and corresponds with the lines of masticatory forces. The roentgenograms show some definite trajectories beginning to form in the angle area, the region of the coronoid process, and diagonally across the ramus toward the condyloid process. The close proximity of the developing teeth to the mandibular canal can also be clearly visualized. The bridging of the trabeculae between the roots of the teeth showing a definite alignment of the trajectories to resist the forces of mastication is especially noteworthy at this stage of development.

Fig. 3.—The mandible of a 7-year-old child showing the relations of the developing teeth and the pattern of trabeculation.

THE ADULT MANDIBLE

In the adult, the height of the ramus is much increased, thus compensating for growth of the alveolar processes and for the increased interarch distance between the upper and lower jaws. Although the trabeculae are undergoing constant changes throughout life, they have a definite pattern in the alveolar processes, the body, and the rami of the mandible.

In studying the average adult mandible with the teeth in position, some outstanding features are evident. Beginning with the alveolar process, these are:

1. The alveolar process is quite narrow labiolingually in the anterior part. There is very little cancellous bone in the incisor and cuspid area opposite the entire length of the roots of the teeth. In most jaws, the cortical plates and the bone of the socket (lamina dura) are fused (Fig. 4). Rarely can any zone of spongiosa be found lingual to the apical portion of the socket of the tooth. Below the apices of the roots, the trabeculae are connected to the inner surface of the surrounding cortical bone. The pattern in this area is such as to resist the forces which may tend to bend the mandible.

2. The positioning of the sockets of the bicuspids and molars in the spongy portion of the bone, as regards the buccal and lingual cortical plates, is more variable. In some instances, some trabeculae can be found lingual to the root of the tooth; in some, the trabeculae are between the tooth and the buccal plate; in

some, the tooth is completely surrounded with a small amount of spongiosa; and in some, the teeth are completely surrounded with compact bone.

3. Starting at the midline and progressing posteriorly, the axes of the roots of the teeth are located progressively farther toward the lingual side of the body of the mandible, and their long axes incline increasingly toward the lingual surface in the same progression.

4. The bicuspids and first molar teeth are, as a rule, in close relation to the buccal cortical plate. The second and third molar teeth very often show a reversed relation in that the roots are in close relation to the inner or lingual cortical

Fig. 4.

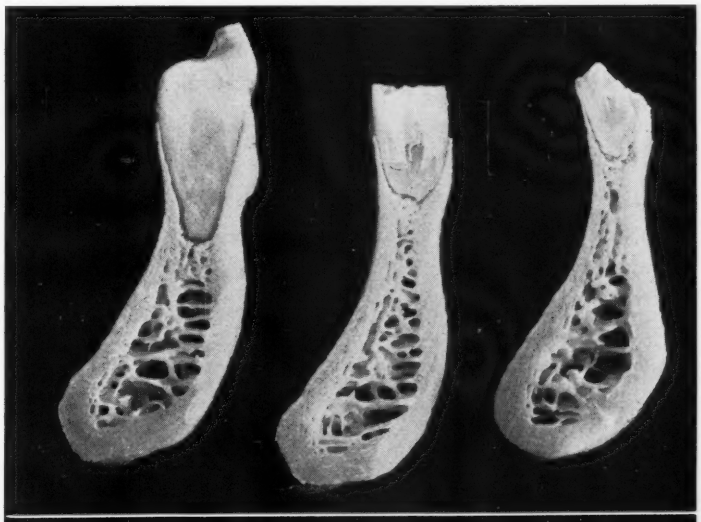

Fig. 5.

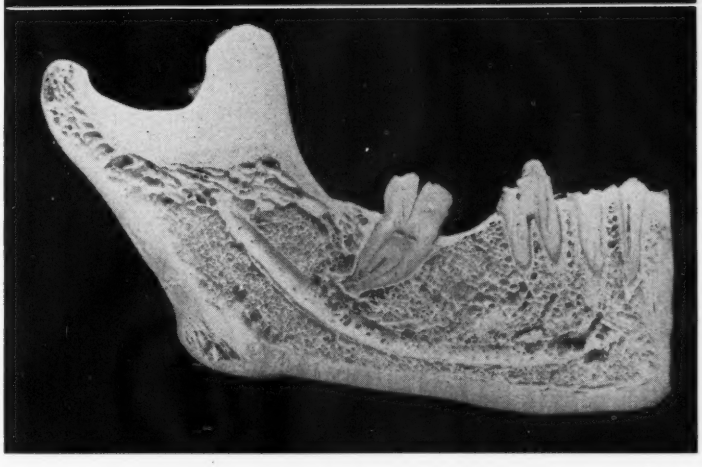

Fig. 4.—Coronal sections of an adult dentulous mandible in the region of the central and lateral incisors and cuspid, showing the thin cortical plates of bone and the arrangement of trabeculae.

Fig. 5.—A sagittal section of an adult dentulous mandible, showing the proximity of the roots of the teeth to the mandibular canal.

plate. The third molar is almost universally in close relation to the lingual cortical plate, which plate may even project on the inner or medial surface as an overhanging shelf. In this way, a fairly thick layer of spongy bone is interposed between the socket and the outer compact layer of the alveolar process on the buccal side. The trabeculae are definitely arranged in the direct line of force applied to this tooth.

Of special interest is the close proximity of the apices of the roots of the third molar to the mandibular canal. As the canal courses anteriorly, it dips downward so that the apices of the roots of the remaining teeth are farther removed from it. The canal is covered or enclosed with a layer of bone similar to the lamina dura of the sockets of the teeth (Fig. 5). The trabeculae surround the outer surface of the lamina dura which is sievelike in character and hence the name "cribriform tube" is applied sometimes to the canal. The trabeculae radiate outward in all directions from this tubular arrangement. The relationship of the teeth to the canal and the morphology of the canal can be very adequately studied in the roentgenograms.

TRABECULAE OF THE DENTULOUS MANDIBLE

Various systems of trajectories of the trabeculae may exist. Among these are those within the alveolar process which resist the forces of mastication as applied to the teeth, and those that are formed in direct response to forces applied by the muscles of mastication at the region of their insertion on the mandible. In fact, these trajectories are interrelated. They transmit the forces applied by the muscles of mastication through the bone, to the teeth, to the temporomandibular joint, and to the different parts of the mandible.

The trajectories of the trabeculae of the alveolar process arise on the outer surface of the lamina dura, or alveolar bone surrounding the teeth. These trabeculae are arranged in approximately a cone-shaped field, ending on the inner aspect of the buccal, labial, and lingual cortical plates of the alveolar process and on the lamina dura of the adjacent teeth. Some of the spongy trabeculae surrounding the apical part of the sockets unite as a trajectory which runs backward below the tips of the teeth. The trajectory then runs diagonally upward and backward through the ramus to end in the condyle of the mandible.

Other trajectories of the trabeculae of the mandible are formed in response to the direct forces applied by the muscles of mastication. These are found in the coronoid process and in the region of the mandibular angle. The trabeculae, below the mandibular canal, point upward and backward toward the trajectories of the ramus and are relative to the forces applied by the masseter and internal pterygoid muscles. The trajectory, which is formed in response to the action of the temporalis muscle, is in the tip of the coronoid process and fans out below into the ramus. Between the trajectories of the coronoid process and that of the mandibular angle, the cancellous bone seems to be almost free of stress as evidenced by the trabecular pattern. When viewed in horizontal section, the trabeculae of the condyloid process present a tubular appearance and are vertically arranged with respect to the longitudinal axis of the process (Fig. 6). The trabeculae of the condyle form trajectories which are continuous with those in the body and ramus that have formed in response

to the forces of mastication. These trajectories extend upward through the ramus and neck of the condyloid process into the head of the process where they fan out toward the articulating surface which is covered by a very thin layer of compact bone.

The trabeculae which resist compressive forces are frequently well marked in the dentulous mandible and will resist the bending forces which are exerted when the muscles of mastication contract.

In some specimens, the spongiosa of the mandible is almost completely replaced by the formation of compact bone. This compact bone obliterates the normal pattern of the trabeculae and the trajectories formed in response to stress. It is unknown whether this reaction is a result of excessive forces applied to the mandible in function or whether it is the physiologic pattern of bone formation peculiar to that individual. This area will require further long-term study.

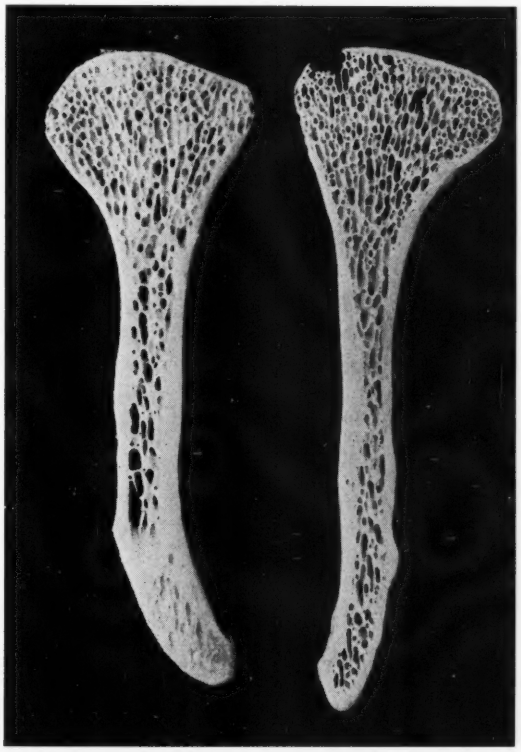

Fig. 6.—Coronal section through the rami and condyloid processes of edentulous (right) and dentulous (left) mandibles.

Other specimens at the opposite extreme are the mandibles in which the trabeculae are very fine, few in number, and with large spaces between them. The alveolar process of these mandibles has a minimum of trabeculae between the lamina dura and the adjacent buccal and lingual cortical plates, and the trabeculation in

the condyle is also very fine and delicate. In general, it seems that, in these specimens, the alveolar process had resorbed in a buccolingual direction, which may later result in the so-called "knife-edge" ridge.

In this study, the roentgenograms of these mandibles proved more satisfactory for the determination of the trabecular pattern as seen from the lateral aspect than did sagittal sections of dried specimens (Fig. 7).

Fig. 7.—Roentgenogram of a dentulous mandible showing the pattern of trabeculation.

TRABECULAE OF EDENTULOUS MANDIBLE

In studying the edentulous mandible, the most marked change seen on gross examination is in the alveolar process which supports the teeth. In response to the law which states that the form of a bone changes as a result of the forces applied to it, the alveolar process undergoes progressive resorption because it is no longer stimulated by the physiologic function of the teeth. This is explained by the term "disuse atrophy," a process which even involves the rami due to the loss of the stimulating action of the muscles of mastication.

In the healing process following the extraction of the teeth, the alveoli are filled with a cancellous type of bone, and a modified cortical layer is formed across part of the crest of the ridge. Apparently, this cortical layer does not extend over the entire surface of the ridge. In all of the specimens studied, a portion of the cancellous bone of the central portion of the mandible could be seen through a defect in the cortical plate (Fig. 8).

The amount of bone that is lost varies greatly from one individual to another, but, in general, the greatest variation is in the anterior region. The external oblique line and the mylohyoid line in the posterior portion of the body of the mandible serve as more or less constant landmarks and undergo the least amount of change. The trabeculae of the body of the edentulous mandible are completely disorganized in form and are much finer in texture than is the case in the dentulous mandible (Fig. 9). There seems to be no definite pattern of trajectories of the trabeculae until the anterior limit of the ramus is approached. In a few instances, the trabec-

Fig. 8.—An edentulous mandible showing the imperfect closure of a cortical plate over the area where the teeth have been extracted.

Fig. 9. —Roentgenograms of an edentulous mandible showing the pattern of trabeculation.

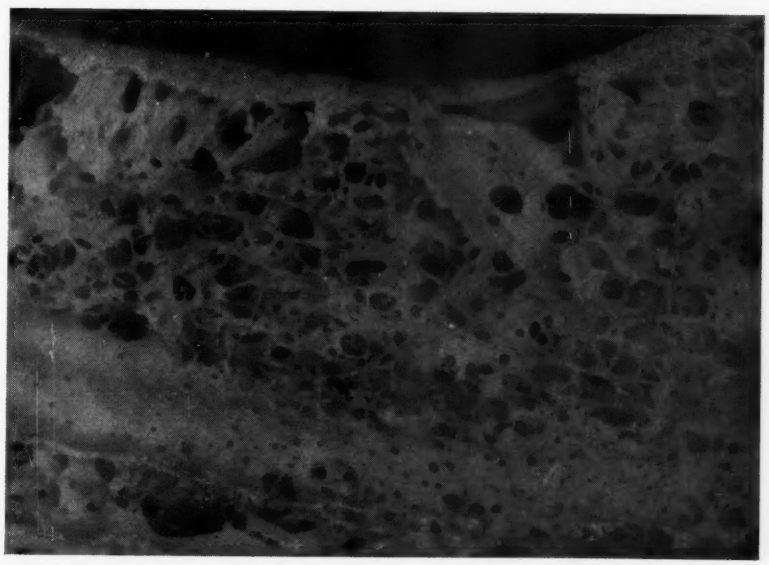

Fig. 10.—A sagittal section through the body of an edentulous mandible, showing the lack of pattern of trajectories, except near the ridge.

ulae are somewhat perpendicular to the residual ridge in the region near its superior border. This suggests that they might have had some function of support; possibly a support for dentures that the individual had worn (Fig. 10).

The trabeculae surrounding the mandibular canal are thinner and not as abundant as they are in the dentulous mandible.

The cortical bone of the body of the mandible is considerably thinner in most cases, especially if the teeth have been missing for some time. There is a definite thinning of the cortical plate of the lower border of the mandible. Some of the thinning may be at the expense of the inner surface, but it appears definitely that some absorption occurs in the external surface of the body of the mandible which leads to an over-all diminution in its size.

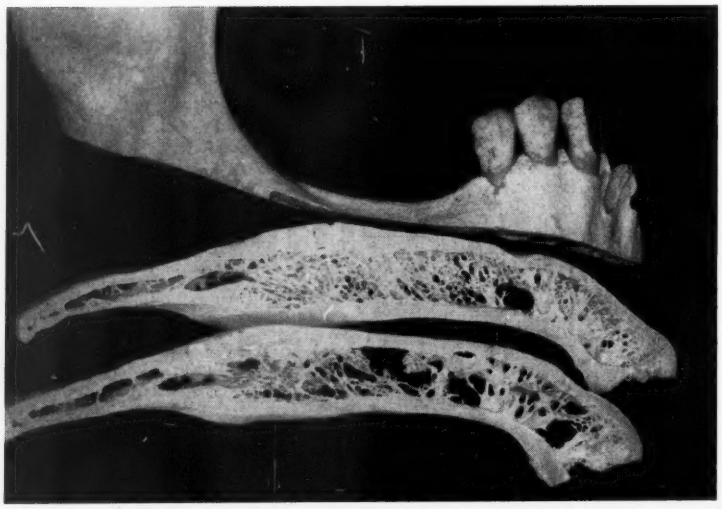

Fig. 11.—Horizontal sections of a partially edentulous mandible showing the trabecular pattern in the region where teeth are present and where they are absent.

In some specimens, the resorption of the bone seems to leave nothing but the cortical plates which are greatly thickened and exhibit a disappearance of the trabecular pattern. This may be so extreme that the mandible is composed actually entirely of solid compact bone. At the other extreme, some mandibles show a very thin cortical plate of bone over all, and very fine trabeculations throughout the interior portion, but the trabeculations do not show any definite pattern.

The trabecular pattern of the ramus, including the coronoid and condyloid processes, remains fairly constant whether the teeth are present or not. In general, the only change that is evident following the loss of teeth is that the trabeculae become finer, and the mass of the bone is reduced.

The condylar process undergoes the least change of trabeculation of any portion of the bone as a result of the loss of teeth. The changes that do appear are the changes that appear in all bones as a result of aging and a general diminution in function.

It has been claimed that the angle of the mandible changes during life as a result of the aging process and the loss of teeth. However, it may be that the pattern of resorption is such that this is not true, but only *appears* to be so because of the change in the external form of the parts of the bone and not a change in the angle.

TRABECULATION OF THE PARTIALLY EDENTULOUS MANDIBLE

The major change in the pattern of trabeculation in the partially edentulous mandible occurs in the area where the teeth are lost. The pattern in the areas in which the teeth are present has been described with the dentulous mandible, and the patterns in the edentulous portion have been described previously with the edentulous mandibles.

The change in the partially edentulous mandible, in the region where the teeth have been extracted, consists of a disorganization and disorientation of the trabeculae from the typical patterns of bridged and radiating trabeculae surrounding the teeth. The trabeculae are changed to the finer, less dense pattern which is characteristic of the edentulous area. There does not seem to be any other significant change either in the trabecular pattern or in the gross structure of the bone except resorption (Fig. 11).

CONCLUSIONS

In this study of the human mandible from an anatomic and morphologic standpoint, it was found that:

1. Roentgenograms are as effective in revealing the architecture of bone as the ground and decalcified sections.
2. Roentgenograms provide a means of studying the mandibular development and changes in structure that occur over long periods of time and perhaps during the life cycle of an individual.
3. The greatest change in the trabecular pattern of the mandible throughout the life of an individual is in its alveolar process.
4. The trabecular pattern of the body of the mandible, upon the loss of the teeth and the remains of the alveolar process, is reorganized in a more or less random manner.
5. In some of the specimens studied, the trabecular pattern was arranged in such a way that it indicated that there was some adaptation of the structure of the bone to the presence of an appliance in the region near the superior surface of the alveolar process. It seems possible that the trabecular pattern will rearrange itself in such a manner that it would indicate resistance to the stresses applied through such an appliance.
6. There is no appreciable change in the trabeculae in the angle of the mandible between the dentulous and edentulous conditions.
7. There is no appreciable difference in the trabecular patterns of the condyle and neck of the condyloid process in the dentulous and edentulous mandibles.

Any useful conclusion drawn from a study of this type must be based on a large number of individuals or specimens studied, since there is an extreme variation in the structure of the mandible from one individual to another.

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A CEPHALOMETRIC STUDY OF THE CLINICAL REST POSITION OF THE MANDIBLE

Part III: Clinical Factors Related to Variability of the Clinical Rest Position Following the Removal of Occlusal Contacts

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CLINICALLY, A CONCEPT OF immutability of the clinical rest position of the mandible is a very confining working hypothesis, leaving no room for either normal or abnormal variations. On the other hand, it is of little clinical value, and may even be misleading, to begin with a working hypothesis of variability if one has no concept of the normal or abnormal factors which influence the degree of variability.

In order to attempt to find out which factors might be of clinical significance, each of the 42 patients in the study described in Part I[1] was studied in regard to more than thirty factors. The data were collected from the dentomedical history, examination, photographs, and roentgenograms. The complexity of clinical research is made apparent by the multiplicity of possibly influential factors. Consequently, it should be obvious that in this kind of a study one cannot reasonably expect to derive results of "statistical significance" from only 42 patients. On the other hand, a careful study of 10 patients can often reveal more about basic concepts than can a careless study of a thousand patients. Moreover, 42 patients may be enough to show variability from patient to patient.

In clinical research, one is often unable to control such factors as age, sex, race, temperament, etc. One has to draw from the clinical pool available. As described in Part I, the objective of this study was to try to establish an over-all base line of the constancy of the clinical rest position following the removal of occlusal contacts under a wide variety of physiologic and pathologic situations. The main requirement was that the treatment plan should include the extraction of remaining occlusal contacts and the construction of dentures. Having once established a base line, or, perhaps more properly, a base *range,* one can then perform several more limited studies of specific factors, as Cohen[2] has done recently in regard to head position.

Read before the Academy of Denture Prosthetics, Columbus, Ohio, May 2, 1957.

Received for publication Aug. 24, 1957.

Part I. The Variability of the Clinical Rest Position Following the Removal of Occlusal Contacts was published in the J. PROS. DEN. 6:504-509, 1956. Part II. The Variability in the Rate of Bone Loss Following the Removal of Occlusal Contacts was published in the J. PROS. DEN. 7:544-552, 1957.

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For convenience of study, the three groups which were described in Part I will be maintained. Group A: those patients (11) who showed an increase in resting vertical dimension; Group B: those (9) who fluctuated about their individual pre-extraction base lines; and Group C: those patients (22) who showed a decrease. The average and maximal changes for each patient are shown in Fig. 1.

Unfortunately, it is not reasonable to publish all of the raw data collected on these 42 patients. In order to simplify the presentation of these complex data, discussion will be limited to six groups of factors. An attempt will be made to enumerate the various factors within each group of factors, to describe the complex interplay within each group, and finally to describe how the various groups of factors may supplement or cancel out one another to achieve a certain net effect for each given patient. The following groups of factors will be presented: (1) tooth-bone factors; (2) tongue factors; (3) lip factors; (4) health and age factors; (5) neuromuscular factors; and (6) factors suggesting previous closure.

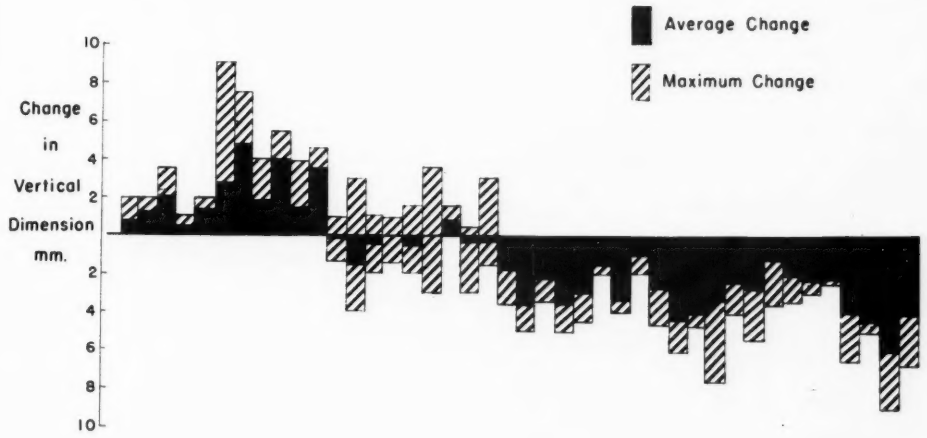

Fig. 1.—Average and maximal changes in resting vertical dimension following the removal of the remaining occlusal contacts. Of the 42 patients, 11 showed an increase, 9 fluctuated about their individual pre-extraction base lines, and 22 showed a decrease. For complete data, see Part I.[1]

TOOTH-BONE FACTORS

If one studies lateral skull roentgenograms of the 42 patients in this study, the wide variety in the shape, size, and position of the mandible is apparent. Each of the component parts (condyle, neck, coronoid process, ramus, angle, and body) may vary in height, anteroposterior width, and relation to the other parts. Presumably, the third dimension (lateral), which is not shown on a lateral roentgenogram, would have similar variations.

Likewise, although somewhat less obvious, the maxillae vary widely from patient to patient in height, anteroposterior width, and position. Then if the

relation of the mandible to the maxillae is studied, three main possible relationships can be observed (Fig. 2). These 3 patients have maxillae of approximately the same size. No. 31 shows a mandible which is proportionate in size, shape, and position whereas No. 151 shows a mandible which is disproportionately small, and No. 78 shows a mandible which is disproportionately large.

By studying such tracings, it is apparent that the interarch distance depends on the relative height of the mandible and the maxillae.

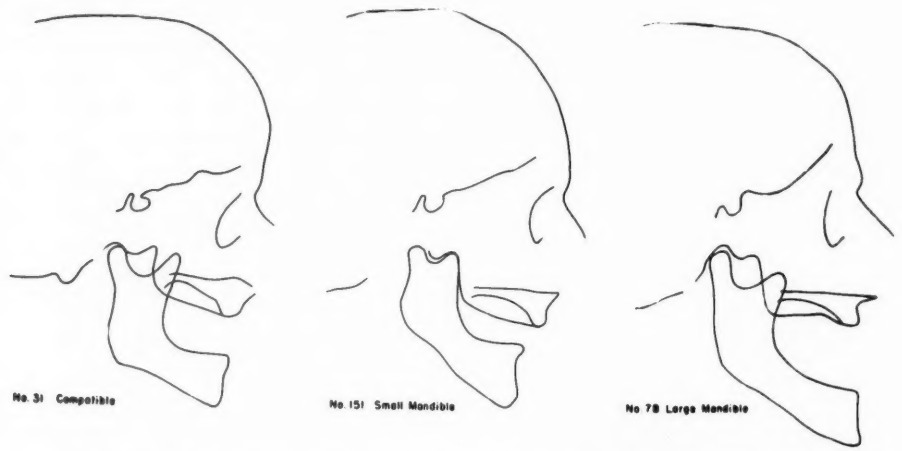

Fig. 2.—Tracings of lateral skull roentgenograms of 3 patients, showing three types of maxillomandibular proportions.

In addition to maxillomandibular disproportion, there may be disproportion in tooth-jaw size. It is common practice to extract four bicuspids or four third molars for lack of anteroposterior space when a person has large teeth and small jaws. Strong presumptive evidence that teeth can also be too large vertically for the existing bony and muscular framework is found in such common clinical conditions as marked vertical overlap, fanning of anterior teeth, tilting of posterior teeth, infraeruption or depression of occlusal stops, severe attrition, absence of a free-way space, and teeth that look too big.

That these disproportions may be caused hereditarily by the mixture of genes from two parents is suggested by the remarkable study of Stockard[3] and Johnson.[4] By crossbreeding purebred long-snouted dogs with purebred short-snouted dogs (Fig. 3), they obtained mongrels with some of the characteristics of each parent. In the second generation, the changes are even more bizarre, with even less chance that two animals would receive exactly the same genetic composition from their hybrid parents. General body characteristics, such as height, length, and weight are influenced genetically. Likewise, specific characteristics, such as color of hair, bend in the tail, erectness of the ears, and disproportionately small mandible, are also controlled by genetic laws of dominance and recession. Fig. 4 shows the mixture of bone and tooth patterns in first and second hybrid generations descended from a purebred dachshund and a purebred Pekingese.

Even in the highly controlled studies of Stockard[3] and Johnson,[4] it is difficult to separate the influences of heredity and environment. In the last analysis, the conclusion seems inevitable that every human being is a unique product of his heredity and environment.

If there is a disproportionately small mandible, or if the teeth are disproportionately large in vertical height relative to the underlying bony and muscular framework, the resting vertical dimension may or may not decrease following the extraction of occlusal contacts depending on several other factors as described later on in this article. In general, however, there was a considerably greater percentage

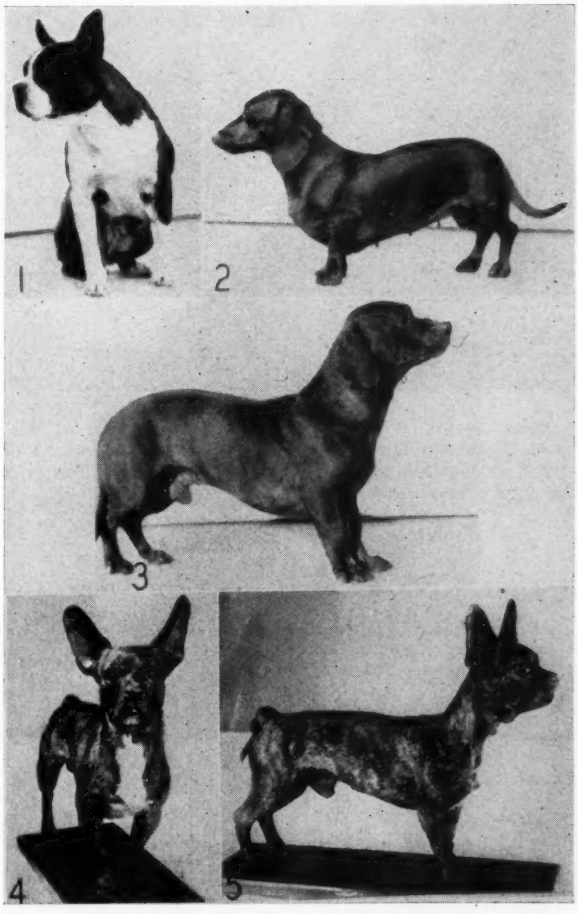

Fig. 3.—*1*, Pure Boston terrier, *2*, pure dachshund, *3*, F_1 hybrid dachshund-Boston terrier, *4* and *5*, backcross of the F_1 hybrid dachshund-Boston terrier with the pure Boston terrier, showing the recombination of characters of the two pure stocks. Note the long dachshund-like ears carried in the erect Boston terrier position, and the short achondroplastic legs of the dachshund in combination with the short, bent tail and coat markings of the Boston terrier breed. (From Stockard, et al.: The Genetic and Endocrinic Basis for Differences in Form and Behavior, Am. Anat. Mem. No. 19. The Wistar Institute of Anatomy and Biology, 1941.)

(55 per cent) of patients with tooth-bone disproportion in Group C than in either Group A (9 per cent) or Group B (22 per cent) (Fig. 5).

TONGUE FACTORS

Cephalometric roentgenograms reveal that, in some patients, the tongue is consistently high in position when at rest, almost completely filling the oral cavity,

Fig. 4.—Lateral view of skulls of dachshund (1) and Pekingese (2) with first (10 and 11) and second (20-23) hybrid generations. Note the relatively small mandible of No. 23. (From A. LeRoy Johnson: The Constitutional Factor in Skull Form and Dental Occlusion. Am. J. Orthodontics & Oral Surg. 26:627-663, 1940.)

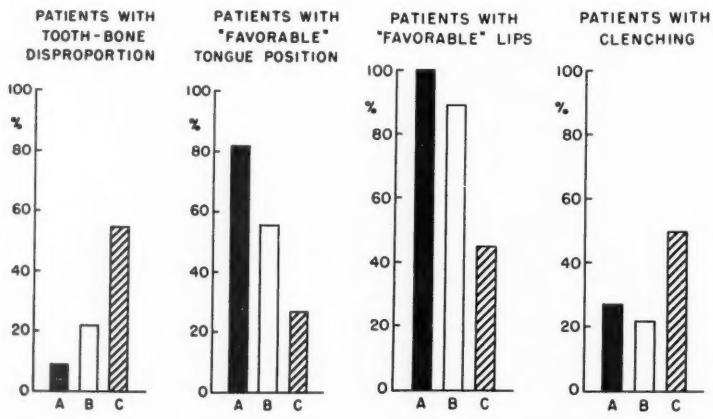

Fig. 5.—Percentage of patients in each group with tooth-bone disproportion, "favorable" tongue position, "favorable" lips, and clenching or other closing habits.

or at least touching the ridges or anterior part of the palate, and in other patients, the tongue is consistently low relative to the occlusal plane and never touches the maxillae when at rest. In some patients, the tongue position fluctuates in a more medium position, sometimes touching the palate, sometimes not.

Tongue size is relative to the bony framework of the oral cavity. Fig. 6 shows tracings of No. 53 with a high or "favorable" tongue and No. 69 with a low or "unfavorable" tongue.

These observations are not inconsistent with the clinical observations that, in some patients, the tongue seems to fill the oral cavity while in others the tongue seems small, atrophic, and low.

Johnson's[4] work with dogs suggests a strong genetic influence on tongue size as in the dog in Fig. 7, with the short jaws derived from one parent (Pekingese) and the long tongue from the other (dachshund).

When occlusal contacts are removed, not only are the mechanical stops removed but also the "neuromuscular stops," i.e., reflex receptors which stimulate reflex inhibition. There are many such receptors located in the periodontal membranes. It may be postulated that if some of the reflex inhibition is removed, the closing muscles may tend to shorten until sufficient other stops are called into play, whether they be neuromuscular or mechanical. Perhaps the contact of the tongue with the maxillae is such a neuromuscular stop and, in certain patients with a large tongue, even a mechanical stop.

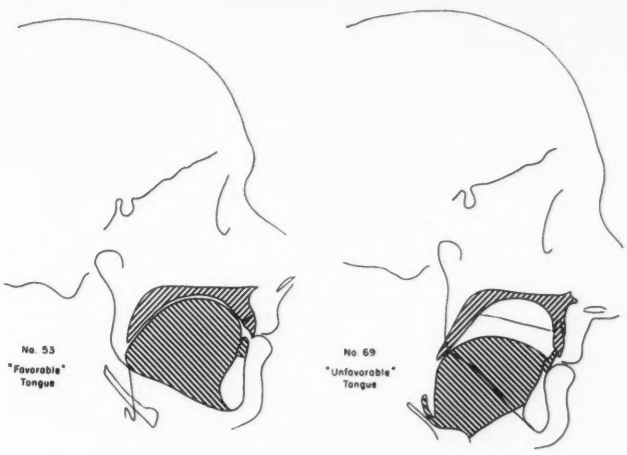

Fig. 6.—Tracings of lateral skull roentgenograms of 2 patients, showing two types of tongue position relative to the oral cavity.

At any rate, in Group A, 82 per cent showed favorable tongue position; in Group B, 56 per cent; and in Group C, only 27 per cent (Fig. 5).

It may also be postulated that the amount of contact of the tongue with the maxillary denture is one of the factors influencing the amount of difference in the rest position with and without dentures.

LIP FACTORS

Similarly, the lips may play the role of "neuromuscular stops." If there is good mass, body, and tone to the lips before the teeth are extracted, if they are long enough to contact one another at rest, and if they meet each other in an end-to-end relationship, they may be said to be "favorable" for the role of neuromuscular stops in the minimizing of decrease in the resting vertical following the extraction of occlusal stops (occluding teeth).

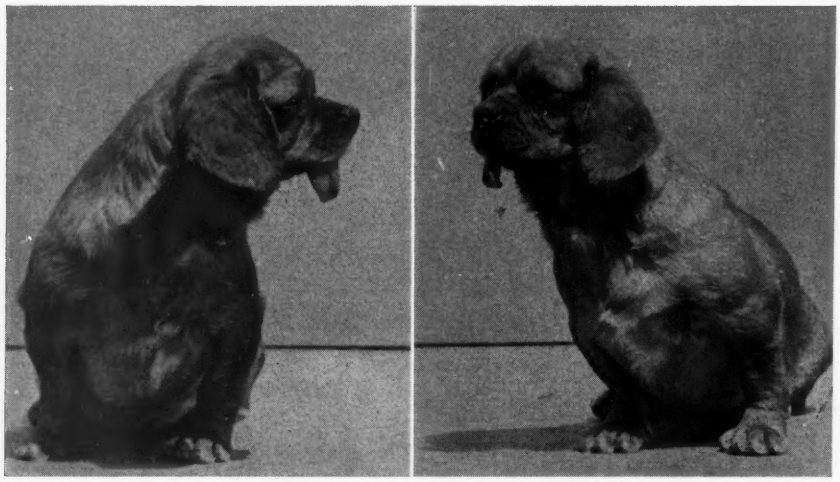

Fig. 7.—F_3 dachshund by Pekingese, showing a tongue anatomically too large for the oral cavity. (From A. LeRoy Johnson: The Constitutional Factor in Skull Form and Dental Occlusion, Am. J. Orthodontics & Oral Surg. 26:627-663, 1940.)

However, if the lips are thin and flaccid and "fall in" when the teeth are extracted, if the lips are short, if there is an overjet of the lips due to a disproportion of the bony or dental framework, or if the lips tend to pout or evert, there may well be an "unfavorable" situation for the maintenance of the status quo.

In our study, 100 per cent of Group A had "favorable" lips; 89 per cent of Group B; and only 45 per cent of Group C (Fig. 5). As with all factors, the presence of favorable lips may or may not be influential in maintaining rest position.

HEALTH AND AGE FACTORS

Clinically, one would anticipate that poor health and advanced age would encourage decrease in the resting vertical dimension. That this was true in several of the patients in this study seems clear; but, as usual, there were exceptions in all directions.

There was a wide range of age in each group and a close similarity of the average age for each group. If an arbitrary line is drawn at 60 years, a slightly greater percentage of the patients over 60 years of age were in Group C than in Groups A or B in this study.

However, chronologic age is not always a good gauge of physiologic age. For example, patient 104 was a young 73 years and patient 63 an old 56 years. For this reason, a clinical evaluation of the patient's health has been grouped with the age factor. Obviously, this is a highly personal and un-scientific measure; but, nonetheless, a highly necessary clinical procedure.

Certain unusual aspects should be mentioned concerning five of the patients.

Patient 97, who showed the greatest average increase in resting vertical dimension, had a large mandible, small teeth, and a free-way space of only 1 mm. During the period of study, he was convalescing from a major surgical procedure. As the fatigability which he had at the beginning disappeared, his resting vertical dimension increased.

Patient 88, who showed pathologic variability in the rest position, had marked muscular rigidity due to parkinsonism and had the typical "stone face." He was a mouth-breather.

Patient 96, who likewise showed pathologic variability in the rest position, had a form of spastic hemiplegia.

Patients 69 and 72 were severely ill postoperative patients on whom the dental treatment plans were not completed because they did not improve as had been anticipated.

Although it is apparent that some of the patients that varied most were not average dental patients, three other concepts should also be emphasized. First, all of these patients needed dental treatment. Second, not all patients that come into the dental office are "average" patients. Third, some of the patients who varied the most—e.g., patients 118, 116, 110, 51, 78, 60, 56, 90, 66, 84, 109, 33, 101, 13, 98, 53, 114, and 104—were normal healthy "average" patients who might walk into any dental office.

NEUROMUSCULAR FACTORS

Since the rest position of the mandible is basically a postural position, neuromuscular factors must be considered.

A history of bruxism or other clenching habits is more commonly found in Group C (50 per cent) than in either Group A (27 per cent) or Group B (22 per cent) (Fig. 5).

Fatigability, a factor which was not measured, could be arrived at only by a clinical evaluation of the history and patient behavior. Hence, again we have a pseudoscientific, but nevertheless immensely important clinical factor. Fatigability was most commonly found in Groups B and C.

There are two neuromuscular factors which might contribute to a maintenance of the status quo. First, mouth-breathing is often a habit of long standing and is probably unrelated to the presence of teeth. Second, 3 patients (53, 104, 105) exhibited an excessive self-consciousness about the fact of missing teeth. All three were in Group A.

FACTORS SUGGESTING PREVIOUS CLOSURE

If a patient is to have remaining occlusal contacts removed, it must be assumed that the patient has severe dental disease; that he is a "dental cripple."

If the patient is a dental cripple, how abnormal is his mandibular posture? There may already have been a closure (decrease in the resting vertical dimension), even though there are some remaining occlusal contacts. If there has already been a decrease, then one would expect less additional decrease following the extractions or perhaps even an increase in the resting vertical dimension. On the other hand, previous closure in spite of occlusal stops may indicate a strong tendency for

TABLE I. SOME CLINICAL FACTORS WHICH MIGHT TEND TO MINIMIZE CLOSURE OF THE CLINICAL REST POSITION FOLLOWING EXTRACTION OF REMAINING OCCLUSAL CONTACTS

GROUP	CASE	AVERAGE CHANGE	TOOTH-BONE	TONGUE	LIP	HEALTH-AGE	NEURO-MUSCLE	PREVIOUS CLOSURE
A	97	+4.8	+	+	+	+	+	+
	104	+4.0	+	+	+	+	+	0
	114	+3.3	+	+	+	+	−	+
	88	+2.8	+	−	+	−	+	0
	53	+2.0	+	+	+	+	+	0
	98	+1.8	−	−	+	+	−	+
	105	+1.4	+	+	+	+	+	0
	32	+1.3	+	+	+	+	−	0
	75	+1.3	+	+	+	+	+	0
	31	+0.8	+	+	+	−	−	+
	65	+0.6	+	+	+	+	+	0
B	103	+0.8	−	+	+	+	+	+
	76	0	+	+	+	+	+	0
	96	0	+	+	+	−	−	0
	62	−0.1	+	±	+	+	−	0
	113	−0.3	+	±	+	+	+	0
	151	−0.3	−	+	+	−	−	+
	74	−0.4	+	±	+	+	+	0
	80	−0.5	+	+	+	+	−	+
	73	−1.5	+	±	±	±	−	+
C	63	−1.0	+	±	+	−	−	0
	95	−1.3	+	±	+	−	−	0
	59	−1.5	+	±	+	+	−	+
	13	−1.7	−	±	−	±	−	+
	101	−2.1	+	±	−	±	−	+
	33	−2.2	+	+	+	+	−	0
	107	−2.3	−	−	−	−	−	+
	109	−2.3	−	±	+	+	+	0
	84	−2.4	−	+	+	+	+	0
	66	−2.8	+	+	−	+	−	0
	90	−2.9	−	+	+	+	−	+
	56	−3.0	+	±	+	+	−	0
	60	−3.3	−	±	−	+	−	+
	78	−3.3	+	±	+	+	−	0
	51	−3.4	−	±	+	+	−	0
	30	−3.6	−	±	±	−	−	+
	153	−3.8	−	+	+	−	−	+
	110	−4.0	+	−	+	+	−	+
	72	−4.1	−	−	−	−	−	+
	69	−4.3	−	−	−	−	−	0
	116	−4.3	+	+	+	+	−	0
	118	−5.8	−	±	−	+	−	0

\+ Predominantly "favorable" factors.
− Predominantly "unfavorable" factors.
± Variable factors.
0 No factors.

closure. Hence, one might expect further closure. As with other factors, no one rule fits all patients.

Among factors suggesting previous closure may be listed an extreme anterior vertical overlap (8 mm. or more), absence of free-way space, marked attrition or occlusal breakdown, fanning (migration) of anterior teeth, and tilting of posterior teeth.

MISCELLANEOUS FACTORS

Certain miscellaneous factors which were studied showed such overlaps or such similarities in the three groups that no correlation was evident. However, this does not rule out the possibility that in any given patient any one of these factors might be important. These factors included pre-extraction free-way space, pre-extraction vertical overlap, pre-extraction number of teeth, pre-extraction number of occlusal contacts, pre-extraction dental disease (caries, periodontal disease, attrition), and the number of teeth extracted.

CORRELATION OF THE SIX GROUPS OF FACTORS

As indicated above in various ways, no single factor or group of factors can be exactly correlated with the degree of variability of the clinical rest position in all patients. Rather, it seems evident that there is a complex interplay between at least six groups of factors. Perhaps it can be said that if a patient has no disproportions in teeth and bone, if he has favorable "neuromuscular stops" in tongue and lips, if he is not too old and sick, and if he has no clenching habits and does not tire easily, then there probably will be little change in clinical rest position following the extraction of occlusal contacts. If any of these factors are unfavorable, then closure will depend on the relative values of the favorable and unfavorable factors. These values are not easily quantitated; but rather our decisions are based on our "clinical judgment," and not on a mathematical formula.

Table I is in no way intended to quantitate these factors; but it does show several things graphically. (1) Patients in Groups A and B had in general more favorable factors than those in Group C. (2) If the patients are arranged according to the numerical amount of average change, the further down the list one goes, the fewer favorable factors are found. (3) Certain patients in each group had certain favorable factors. (4) Certain patients in each group had certain unfavorable factors. (5) No one factor was always consistent. (6) In some patients, closure occurred despite the presence of favorable factors. (7) In some patients closure failed to occur despite the presence of unfavorable factors.

SUMMARY

1. Each of the 42 patients reported in Part I was studied in regard to over thirty clinical factors.

2. In order to simplify the presentation of the complex data, discussion in this report was limited to six groups of factors: tooth-bone factors, tongue factors, lip factors, health-age factors, neuromuscular factors, and factors suggesting previous closure.

3. Interesting trends were shown for each group of factors, but no single factor or group of factors was exactly correlated with the degree of variability of the clinical rest position in all patients.

4. Closure following the removal of occlusal contacts may or may not occur, depending on the relative values of and complex interplay between certain favorable and unfavorable factors. These values are not easily quantitated, nor are they applicable to a mathematical formula.

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A CRITICAL ANALYSIS OF THE BENNETT MOVEMENT. PART I

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THE DENTAL PROFESSION'S HIGH regard for Norman G. Bennett's epoch-making article,[1] "A Contribution to the Study of the Movements of the Mandible," published April 27, 1908, has been sustained for several decades without much comment or criticism. A review of the literature reveals that Bennett's work and fame rest not upon the major contribution he made to dentistry, but rather upon the weakest element of his work, which is usually referred to as the Bennett movement. In fact, the profession has all these years been reading into Bennett's famous paper an intention he never had. It should be clear from an attentive perusal thereof, that Bennett never purported to propose a new or revised status for lateral mandibular movements. Furthermore, no such purpose can be discovered in any of his subsequent papers in this area. Bennett's main objective, in his 1908 paper,† was to demonstrate that "no single fixed centre of rotation exists for ordinary opening or closing mandibular movements," and seven out of a total of eight illustrations were devoted exclusively to this very subject.

The now celebrated "Bennett movement" (the Bennett lateral movement) was mentioned only casually in Bennett's article, and it was incidental to the main discussion. It emerges almost as an insignificant by-product of the observations in which Bennett was engaged in his experiment. Though he himself claimed no factuality for his notion of the lateral movement, our colleagues have seemed to accept it as a scientific fact without subjecting it to a critical analysis.

This unfulfilled need for a critical analysis of the validity of the "Bennett movement" impelled me to undertake some experimental research in that direction. This article is a report on the techniques, procedures, and findings of these studies. However, it is advisable to review what is understood under the term "Bennett movement" and to recall the implications thereof.

According to Bennett, an *extreme* lateral mandibular movement with the teeth in *continuous* occlusion is always associated with a glide or shift of the mandibular condyle to the right or left working side. When this type of mandibular movement takes place to the right side, there should be observable a rather considerable shifting of the right condyle outward, to the right side away from its articular surface, and slightly downward. Exactly the same phenomenon should be observed when

Received for publication Aug. 17, 1957; revised by the author Dec. 26, 1957.
Part II will appear in a subsequent issue of the JOURNAL OF PROSTHETIC DENTISTRY.
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†Editor's note: The original article by Norman G. Bennett was reprinted in the JOURNAL OF PROSTHETIC DENTISTRY 8:41-54, 1958.

the movement is effected to the left side. Bennett maintained that "these two movements represent as nearly as possible those of normal mastication." These specific mandibular movements, with their corresponding condylar shifting or gliding to the right and left working side, have been referred to as the "Bennett movement."

Bennett also described two other lateral movements representing a combination of *extreme* mandibular opening with *extreme* right or left lateral movements. In these instances, according to Bennett, "the condyle again leaves its articular surface to quite a considerable extent, the movement amounting to almost exactly 3 mm."[1] These lateral movements are usually not included by the dental profession under the term "Bennett movement."

This Bennett concept of lateral mandibular movements with all its vague implications and diagrammatic representations could not be substantiated after being subjected to a careful critical investigation.

METHODS OF INVESTIGATION

Several avenues of approach have been utilized in this investigation: (1) the study of both museum and medical skulls; (2) the study on cadavers with the coronal portion of the skull and the cranial contents removed exposing the superior surface of the condyle and the extreme lateral pole of the condyle for observation and measurements; (3) roentgenographic studies; (4) cinefluorographic studies; (5) electromyographic studies; and (6) studies by the optical method as described by Bennett (to be included in Part II).

STUDY OF SKULLS

Museum Skulls.—A great number of skulls with excellent dentitions of the skeletal collection from Western Illinois were examined. These were collected by Dr. P. T. Titterington, of St. Louis, from the Indian Mounds along the Mississippi River bluffs in Jersey County, Illinois. This skeletal collection is now the property of the Smithsonian Institution, Washington, D.C. A number of Greenland skulls were also examined at the American Museum of Natural History, New York City, and some skulls were examined at the Wistar Institute, Philadelphia, Pa. Sizable skull collections in private ownership by commercial institutions and individuals were also examined.

The Indian and Greenland skulls which were observed have dentitions that are worn considerably by attrition. The lateral guidance of the occlusal surfaces of these dentitions is so intimate and well defined that the condylar guidance must be assumed to follow it and be in harmony with the tooth guidance. Careful measurements and observation on 175 of these skulls have revealed that only in three instances was there any semblance of a "Bennett movement." In all other instances, the mandibular condyle on the working side had rotated apparently around its vertical axis without shifting laterally in the least. If anything, a slight gliding of the mandibular condyle backward and upward was observed in the vast majority of these instances.

An observation which may have misguided some investigators is that when the mandibular condyle rotates around its vertical axis on the working side, the

lateral pole of the same condyle becomes more conspicuous on the lateral side without effecting a gliding laterally in the least. This is due to the fact that the position of the condyles in their respective glenoid cavities is such that their lateral poles are directed forward and outward, while the medial poles are directed posteriorly and medially. With a movement of the mandible to a right lateral working position, the right condyle becomes the vertical rotating axis around which the mandible rotates toward the right side. With this rotation of the mandibular condyle around its vertical axis, the lateral pole of the condyle becomes more prominent laterally when it lies in the same horizontal line with its adjacent medial pole. Thus, the lateral pole on the working side becomes more prominent in the lateral direction without the slightest gliding of the mandibular condyle *bodily* in an outward direction (Fig. 1). Careful measurements on numerous skulls substantiate this observation. This is particularly true when working with medical skulls and medical wet specimens.

Medical Skulls.—Medical skulls, with their cranial cavities open from the top, lend themselves even better than the museum skulls to observation and measurements. On museum skulls, all that could be used for measuring mandibular movements in various directions was a pair of dividers. For making corresponding measurements on medical skulls, some instruments of my own design were constructed (Fig. 2).

MEASURING DEVICE FOR CONDYLAR MOVEMENTS

The measuring device consists of two vertical aluminum plates, each 35 mm. in length and 15 mm. in width. These two plates are topped by a horizontal plate of the same width but which is only 30 mm. in length. At this point, the horizontal plate is bent vertically upward and measures 20 mm. in height. The two vertical plates are parallel to each other, and from about their middle downward are perforated by six apertures, consisting of two rows of three apertures in each plate. These apertures are arranged symmetrically on the same level on both vertical plates. Six wire rods, of the appropriate diameter, are fitted into these apertures, and these rods lie perfectly horizontal and parallel to each other. Beneath these apertures are two vertical slots, one in each vertical plate and on the same level into which is fitted an aluminum blade 6 mm. in width and 6 cm. in length. This blade is parallel to the rods which are sharpened to a point at one end and graduated in millimeters. The instrument is attached rigidly to the vertical plate of the squamous portion of the temporal bone by means of a strong clamp. The clamp holds the instrument in such a manner that the point of the blade effects contact with the extreme point of the lateral pole of the mandibular condyle when the mandibular teeth are in centric occlusion with the maxillary teeth (Fig. 3). The skull is immobilized on a specially prepared board, and lateral movements of the mandible are performed. The corresponding movements of the condyles are observed and measured by the aluminum blade and the six aluminum rods, depending upon the direction of the movement observed (Fig. 4).

In 150 medical skulls, only 4 were found in which the Bennett movement was apparent. Taking into consideration the limitations of mandibular movements of

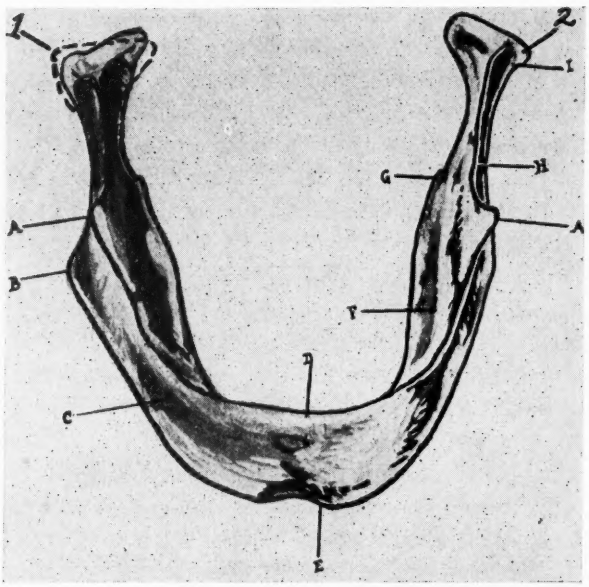

Fig. 1.—When the mandible moves into a right lateral position the lateral pole of the right rotating mandibular condyle becomes more conspicuous laterally, while the medial pole moves slightly forward.

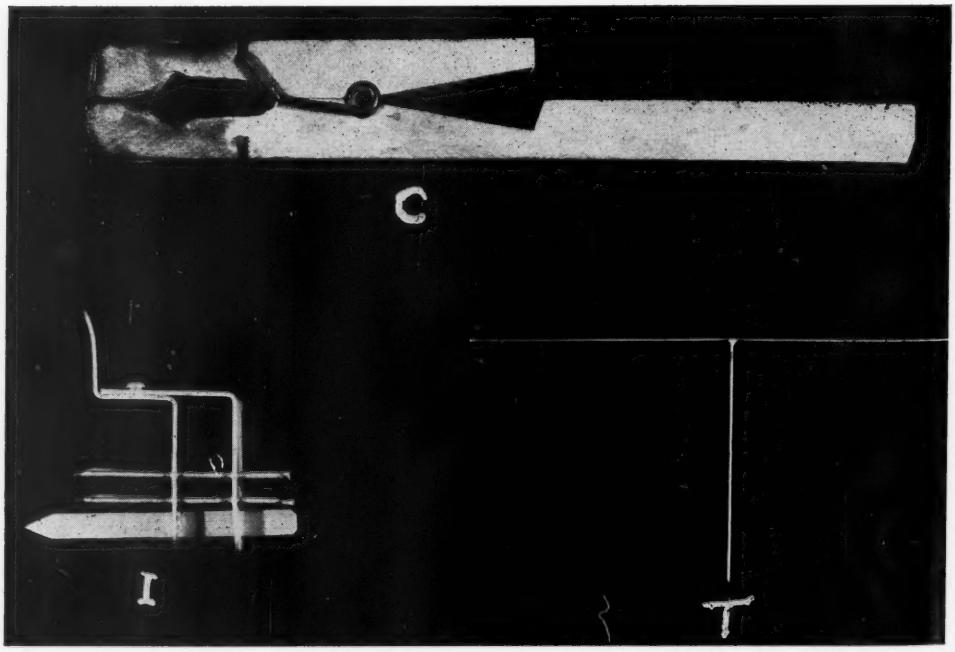

Fig. 2.—*(I)*, The instrument for measuring various positions of the mandibular condyle on the working side, as compared with the position of the same condyle when the mandible is in centric occlusion. *(T)*, The *T*-wire attachment adapted for cementation into the superior and lateral aspects of the condyle for study of the various deviations of the condyles that are associated with various movements of the mandible. *(C)*, The clamp for rigid fixation of the instrument *I* to the skull.

dry skulls when compared with mandibular movements in the living, these studies nonetheless tend to indicate that the Bennett movement is a rare exception rather than the rule.

Fig. 3.

Fig. 4.

Fig. 3.—The measuring instrument is rigidly attached by means of the clamp to the vertical plate of the squamous portion of the temporal bone. The mandibular teeth are in centric occlusion with the maxillary teeth.

Fig. 4.—The mandible is in left lateral working position, and the movement of the condyle is measured by the aluminum blade and the six aluminum rods.

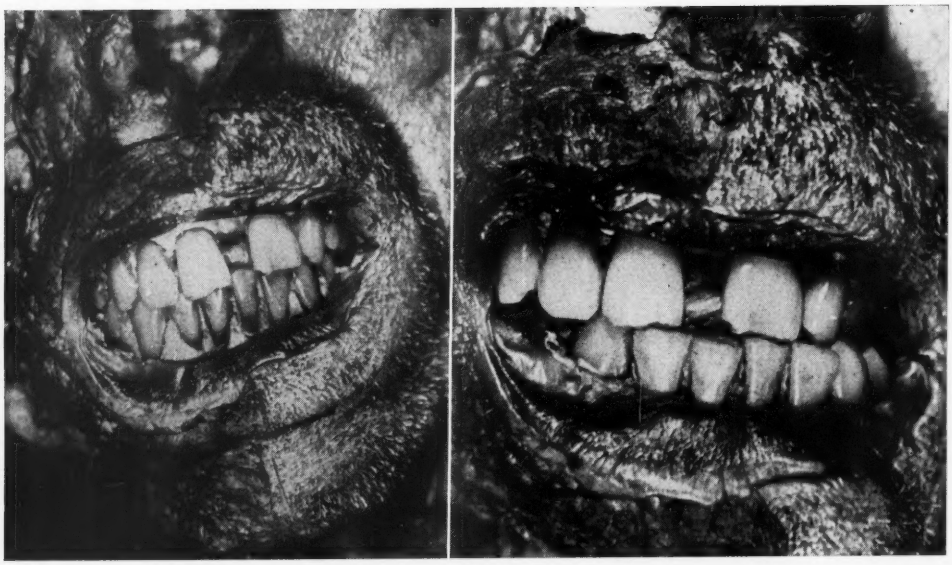

Fig. 5. Fig. 6.

Fig. 5.—A cadaver with the teeth in centric occlusion. Note vertical overlap of teeth.
Fig. 6.—A cadaver with the teeth in left lateral occlusion. Note edge-to-edge bite of anterior teeth and considerable displacement of mandible to left side.

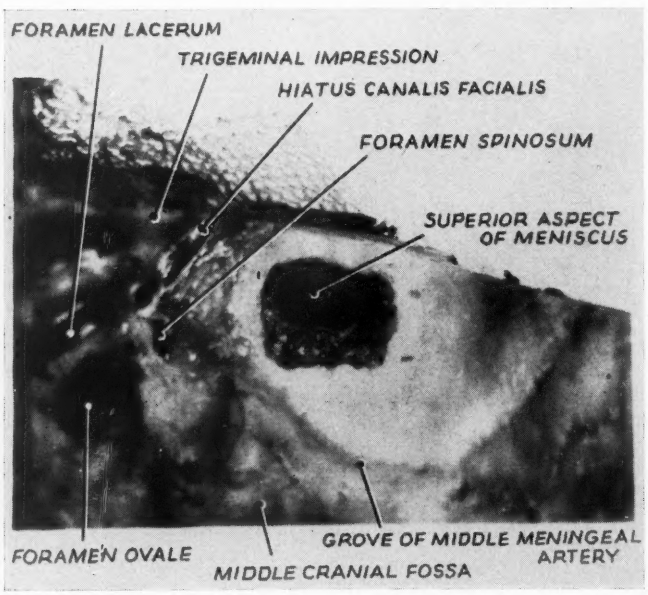

Fig. 7.—The middle cranial fossa viewed from above. The roof of the mandibular cavity was removed, and the entire meniscus was exposed. The meniscus was then completely excised, and the superior surface of the condyle was exposed.

STUDY ON CADAVERS

The second method of investigation of mandibular movements was on fresh cadavers (Figs. 5 and 6). After the crown of the head and the brain was removed, the roof of the glenoid cavity was located. This was removed carefully by means of burs and fine grit stones in such a manner as not to injure the capsular ligament (Fig. 7). The meniscus was excised carefully so that the mandibular condyle was exposed completely to view from the top.

T-WIRE ATTACHMENT IN MIDDLE CRANIAL CAVITY

A specially constructed *T*-wire attachment, consisting of a horizontal rod and a vertical rod that is perpendicular to the horizontal rod, was cemented into the superior surface of the condyle at or near its medial pole. The direction of the horizontal rod is parallel with the sagittal plane of the head when the teeth are in centric occlusion. The horizontal rod measures 11.5 cm. and the vertical rod measures 5.5 cm. The relatively large size of the horizontal rod facilitated study of the most minute rotational movements of the condyle by the corresponding angulation that the extreme ends of this rod assumed with each mandibular rotation.

With the head rigidly fixed, the mandible was moved into a working position and the corresponding angulation laterally was observed on the anterior end of the horizontal rod. The angulation medially was observed on the posterior end of the horizontal rod. These angular rotations of the horizontal rod were easily observable but difficult to measure (Fig. 8). The observation in itself, however, was of a positive nature.

The movements of the cemented vertical rod, on the contrary, lend themselves to measurements with precision by a highly sensitive method involving an adaptation of the Boley gauge. This instrument consists of a main bar with a front jaw rigidly attached to it; the back jaw glides back and forth on the main bar. In my adaptation for this experiment, the front jaw became the movable one and the back jaw the fixed one. This was accomplished by cutting a slot in the vertical plate of the squamous portion of the temporal bone of the wet specimen, of just sufficient width to allow for rigid fixation of the back jaw of the Boley gauge. In this position, the main rod moved in the rigidly stationary back jaw, which was set at a certain angulation to allow the front movable jaw to make contact with the vertical rod of the *T*-wire attachment at a certain vertical level. The vertical rod of the *T*-wire attachment was cemented into the superior surface of the condyle at or near its medial pole, and the horizontal rod was parallel to the sagittal plane of the head.

The front jaw of the Boley gauge was placed in contact with the vertical rod of the *T*-wire attachment while the teeth of the specimen were in centric occlusion. The reading on the scale was noted carefully and recorded. Then the mandible was moved carefully to the left into a working position, and maintained in that position while the front jaw of the Boley gauge was made to contact with the vertical rod of the *T*-wire attachment in its new position. When the new reading was taken on the specimen (Fig. 9), it was found that the vertical rod, and

with it the *medial pole* of the mandibular condyle, deflected forward only 0.4 mm. (These experiments were checked by substituting a fissure bur for the *T*-wire attachment. The cutting end of the fissure bur was cemented into the superior surface of the condyle at its medial pole in lieu of the vertical rod of the*T*-wire attachment. This afforded a more rigid arrangement, Figs. 10 and 11.)

Fig. 8.

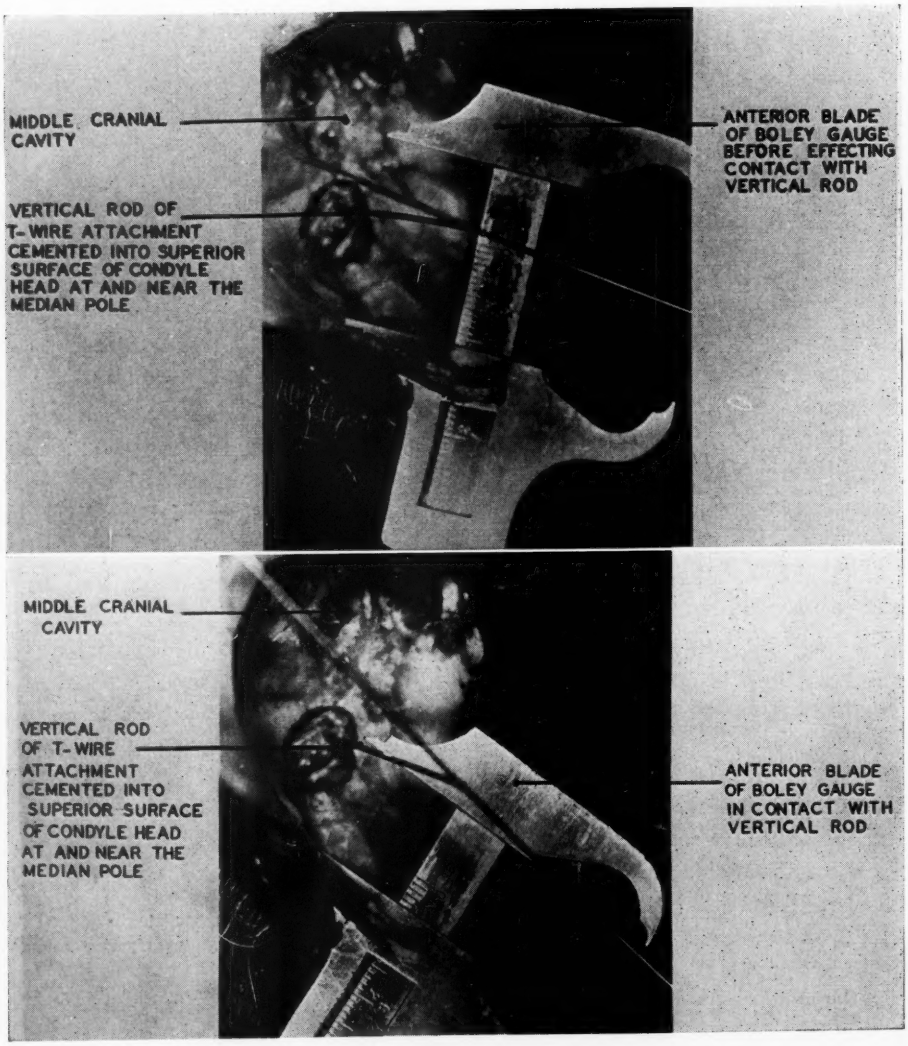
MIDDLE CRANIAL CAVITY
VERTICAL ROD OF T-WIRE ATTACHMENT CEMENTED INTO SUPERIOR SURFACE OF CONDYLE HEAD AT AND NEAR THE MEDIAN POLE
ANTERIOR BLADE OF BOLEY GAUGE BEFORE EFFECTING CONTACT WITH VERTICAL ROD
MIDDLE CRANIAL CAVITY
VERTICAL ROD OF T-WIRE ATTACHMENT CEMENTED INTO SUPERIOR SURFACE OF CONDYLE HEAD AT AND NEAR THE MEDIAN POLE
ANTERIOR BLADE OF BOLEY GAUGE IN CONTACT WITH VERTICAL ROD

Fig. 9.

Fig. 8.—The angular deflection of the anterior end of the horizontal rod laterally and its posterior end medially indicate that the mandibular condyle in lateral working occlusion rotates around its vertical axis.

Fig. 9.—The anterior blade of the Boley gauge is in contact with the vertical rod when the teeth are in centric occlusion, and the reading on the scale is recorded. The mandible is then moved into left lateral working occlusion, and the new reading on the Boley gauge is recorded. The new reading showed a 0.4 mm. deflection of the vertical rod forward.

At the same time, the anterior end of the horizontal rod of the *T*-wire attachment became deflected considerably laterally, and its posterior end was deflected medially. This shows that the working condyle, in this instance, was rotating around its vertical axis until the buccal cusps of the lower teeth effected contact with the buccal busps of the upper teeth. There was no semblance of even the slightest shifting of the mandibular condyle laterally. This does not support Bennett's concept of lateral mandibular movements.

T-WIRE ATTACHMENT ON THE LATERAL ASPECT OF HEAD

Similar investigations were conducted by exposing the lateral pole of the vertically rotating condyle on the working side (Figs. 12 and 13). A small section

Fig. 10.

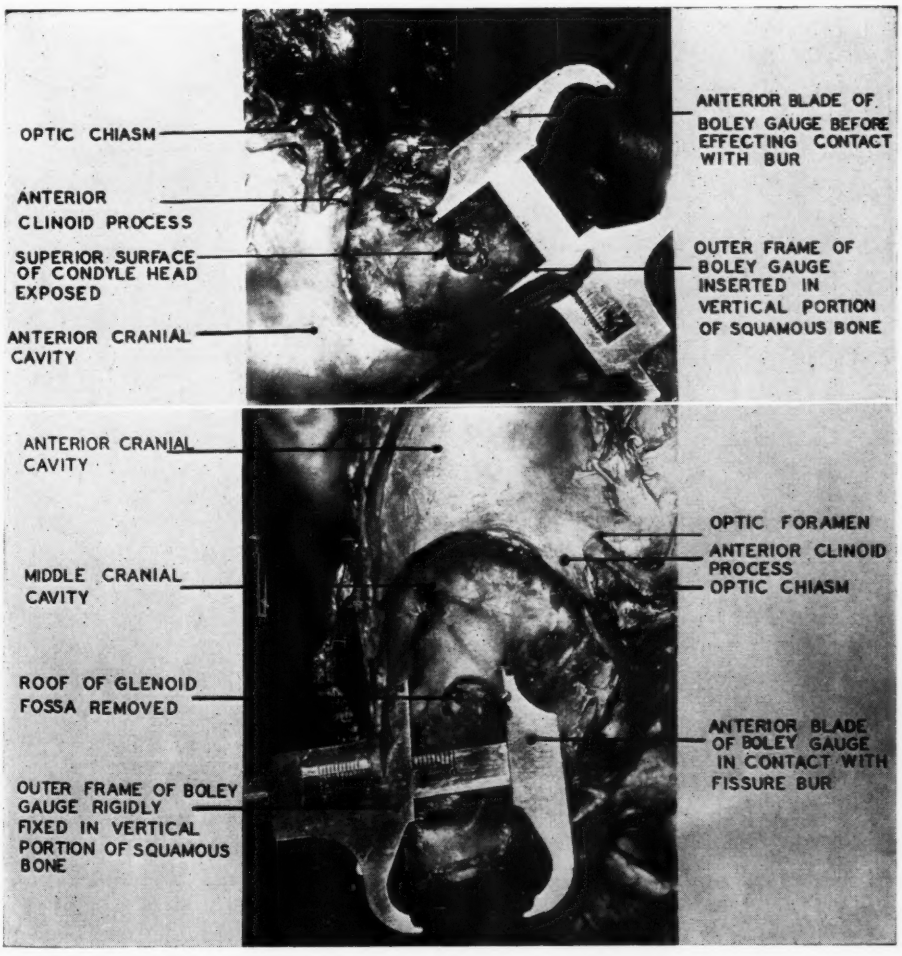
OPTIC CHIASM
ANTERIOR CLINOID PROCESS
SUPERIOR SURFACE OF CONDYLE HEAD EXPOSED
ANTERIOR CRANIAL CAVITY
ANTERIOR BLADE OF BOLEY GAUGE BEFORE EFFECTING CONTACT WITH BUR
OUTER FRAME OF BOLEY GAUGE INSERTED IN VERTICAL PORTION OF SQUAMOUS BONE
ANTERIOR CRANIAL CAVITY
MIDDLE CRANIAL CAVITY
ROOF OF GLENOID FOSSA REMOVED
OUTER FRAME OF BOLEY GAUGE RIGIDLY FIXED IN VERTICAL PORTION OF SQUAMOUS BONE
OPTIC FORAMEN
ANTERIOR CLINOID PROCESS
OPTIC CHIASM
ANTERIOR BLADE OF BOLEY GAUGE IN CONTACT WITH FISSURE BUR

Fig. 11.

Fig. 10.—A fissure bur is cemented in the superior surface of the condyle in lieu of the *T*-wire attachment. Compare with Fig. 8.

Fig. 11.—A fissure bur is cemented in the superior surface of the condyle in lieu of the *T*-wire attachment. Compare with Fig. 9.

of the lateral surface of the capsular and temporomandibular ligaments was dissected away. Care was taken to expose the lateral pole of the mandibular condyle completely without unduly mutilating the lateral surface of the capsular ligament. The vertical rod of the *T*-wire attachment was cemented into the most protruding

Fig. 12.

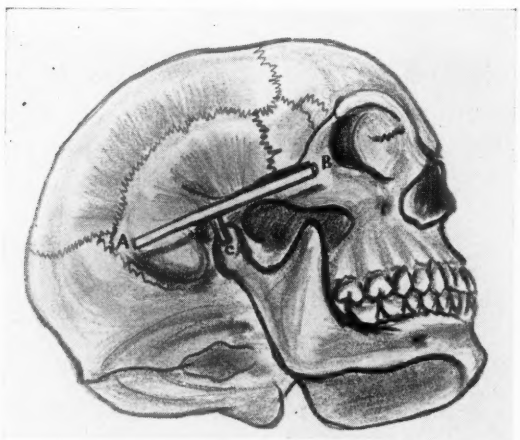

Fig. 13.

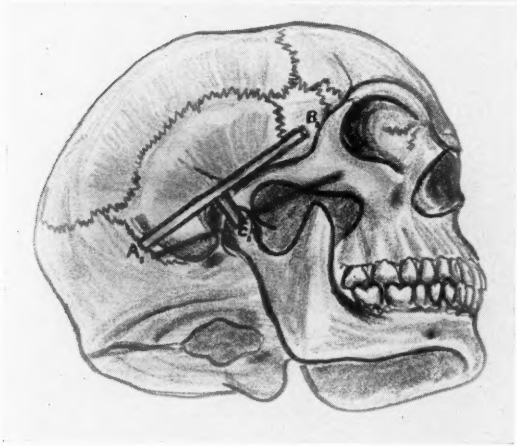

Fig. 12.—A different approach to the study of the same problem. Here the vertical rod of the *T*-wire attachment is cemented into the most lateral prominence of the lateral pole of the condyle. The mandibular teeth are in centric occlusion with the maxillary teeth, and the horizontal rod is parallel with the sagittal plane of the head.

Fig. 13.—The mandible is in a right lateral working position, and the horizontal rod is not parallel to the sagittal plane of the head. Compare with Fig. 12.

lateral point of the lateral pole of the condyle to a depth of about 6 mm. The horizontal rod was parallel to the sagittal plane of the head. The mandible was guided into a working position with the mandibular teeth in continuous contact with the maxillary teeth. It then became obvious that the anterior end of the horizontal rod was deflected laterally and its posterior end was deflected medially (Fig. 14).

The deflection of the anterior and posterior ends of the horizontal rod in these experiments is explained in the following manner. The mandibular condyle, while rotating into a working position around its vertical axis, moves the lateral pole in a posterior direction and the medial pole in an anterior direction. No outward bodily gliding of the condyle itself (Bennett movement) on the working side was observed in these experiments. Thus, neither investigations on dry skulls (museum and medical) nor careful investigations on wet specimen cadavers seem to confirm the conclusions at which Bennett arrived on the basis of the mathematical and mechanical theories presented by his brother.

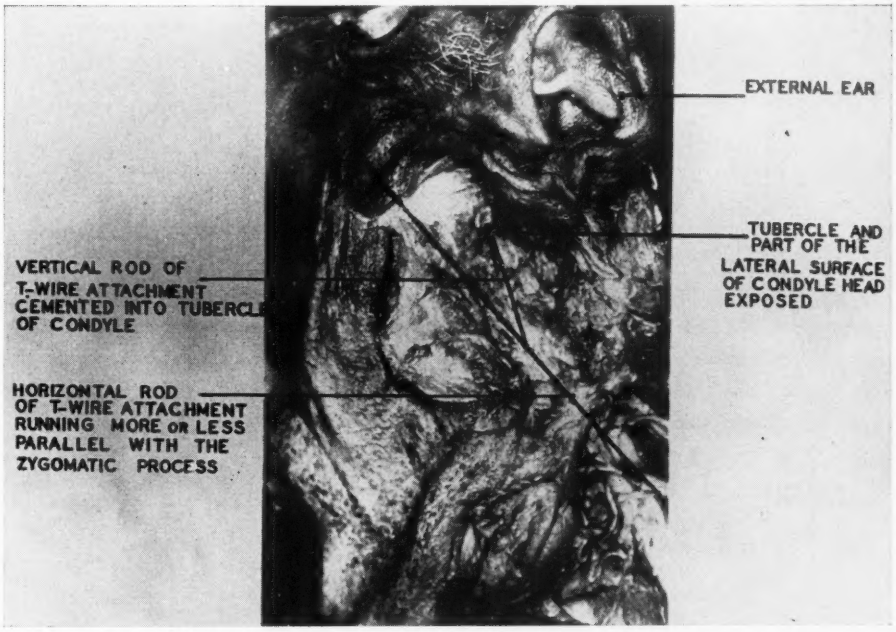
EXTERNAL EAR
TUBERCLE AND PART OF THE LATERAL SURFACE OF CONDYLE HEAD EXPOSED
VERTICAL ROD OF T-WIRE ATTACHMENT CEMENTED INTO TUBERCLE OF CONDYLE
HORIZONTAL ROD OF T-WIRE ATTACHMENT RUNNING MORE OR LESS PARALLEL WITH THE ZYGOMATIC PROCESS

Fig. 14.—A cadaver with the vertical rod of the *T*-wire attachment cemented into the most lateral prominence of the lateral pole of the mandibular condyle. The horizontal rod is parallel to the sagittal plane of the head when the mandibular teeth are in centric occlusion with the maxillary teeth. When the mandible is moved into a lateral occlusion position the anterior end of the horizontal rod deflects laterally, and the posterior end deflects medially.

ROENTGENOGRAPHIC STUDIES

The topography and morphology of the temporomandibular joint, and its relationship to the adjacent superimposed bony structures, are such that vertical rotations or minute displacements of the mandibular condyles cannot be determined reliably by current roentgenographic techniques. No method has been devised yet for *absolute* immobilization of the head and the mandible while exposures for various mandibular positions are made. The oblique shape and position of the condyle in the glenoid cavity and the bony projections (the eminentia articularis, postglenoid process, and the medial and lateral bony lips) surrounding the condyle interfere with precision roentgen ray work in this area.

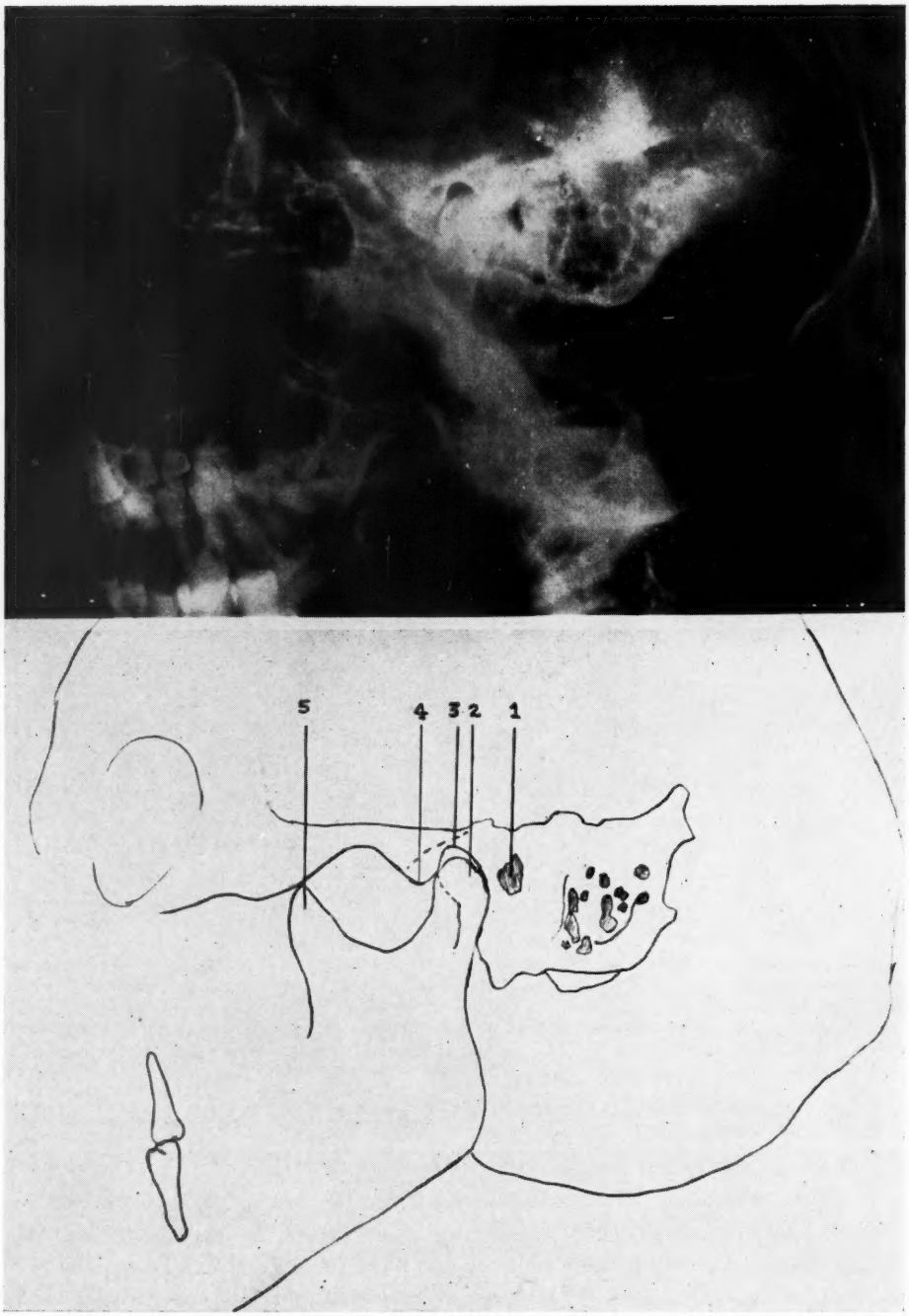

Fig. 15.—Right centric position. *Above,* a roentgenogram of the right mandibular condyle with the teeth in centric occlusion. *Below,* the tracing of these anatomic structures in a static state.

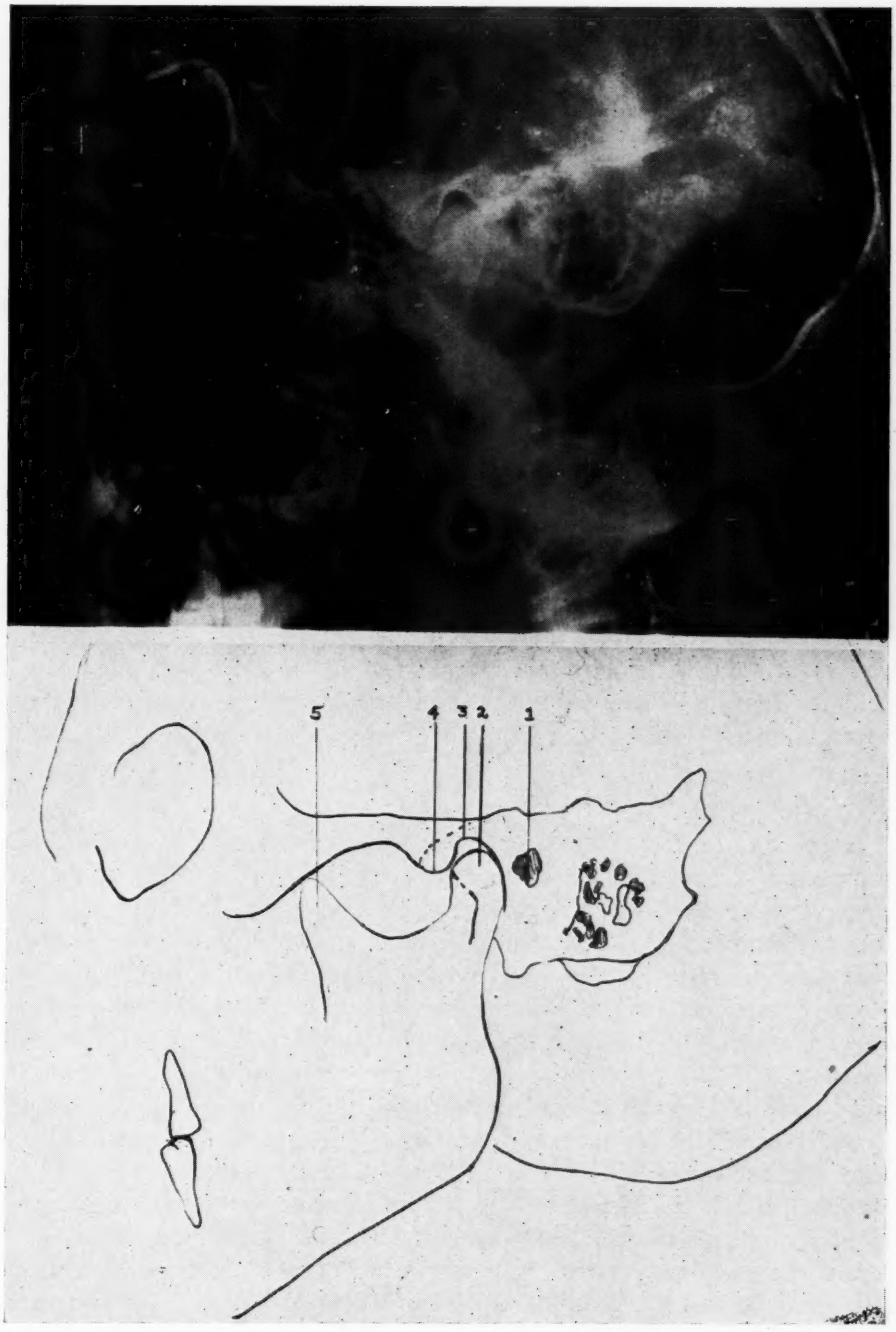

Fig. 16.—Right lateral projection. *Above,* a roentgenogram of the right mandibular condyle with the teeth in lateral working occlusion. *Below,* the tracing of these anatomic structures in a static state. Compare with Fig. 15.

To secure one roentgenogram of a condyle in centric occlusion and another roentgenogram of the same condyle in working occlusion and to read diagnostic features into them is to engage in dangerous speculation. Indeed, the mandibular second molar probably moves 1.0 or 1.5 mm. in its transition from a centric to a working position. Concomitantly, the rotation of the working condyle in the glenoid cavity is so insignificantly small that it does not lend itself to definitive interpretation. To make tracings of these roentgenograms, superimposing one upon another, and to arrive at definitive diagnostic conclusions on this basis alone is also hazardous. The same condyle in the same position, when traced from the roentgenogram by two individuals working independently, might look different. Therefore, while a roentgenographic study of the various condylar positions associated with various mandibular positions may be utilized in an investigation such as this, it cannot be considered conclusive.

However, if the Bennett movement were valid, some evidence to that effect might be expected in roentgenograms secured of the mandibular condyle in centric position and in working position, respectively. Tracings were made by a man in the field of roentgenography who was not aware of the aims and objectives of the research. There was thus less liability to error due to emotional involvement.

Careful roentgenographic studies do not substantiate the concept of the "Bennett movement." If it were a fact, as Bennett maintained, that on the working side "there is a quite considerable movement of the condyle outwards away from its articular surface, and slightly downwards,"[1] such "considerable" gliding of the mandibular condyle laterally and downward would somehow be observable roentgenographically.

CINEFLUOROGRAPHIC STUDIES

In order to set forth fully the significance of cinefluorographic studies of the movements of the condyles, it is essential first to differentiate these studies from roentgenographic studies. In a roentgenogram, the parts that form the subject of any study are seen in a static state. Cinefluorography represents a synchronization of roentgen rays with photographic exposures. As such, cinefluorography exposes the dynamic phenomena that take place in the living organism, whereas roentgenograms are used as a static equivalent for the determination of a kinematic movement.

To test the "Bennett theory," we secured one roentgenographic exposure of the condyle when the teeth were in centric occlusion (Fig. 15) and another exposure of the condyle when the teeth were in lateral occlusion (Fig. 16) and superimposed their tracings (Fig. 17). In both instances, the teeth and condyles, respectively, were seen roentgenographically in static positions.

Let us assume now that we have established the authenticity of the "Bennett movement." In that event, a static point of the condyle, when the teeth are in centric occlusion, could be joined by a line with the same static point of the same condyle when the teeth are in lateral working occlusion. This line could then be considered as the *static equivalent of a kinematic movement.* This, however, would not even remotely suggest that the physiologic movement performed by the condyle

between these two static points was running identically along the line that joins them. The actual physiologic movement is of a much more complex nature.

With the aid of cinefluorography, we sought to establish the exact physiologic movements of the mandible or its condyles. Cinefluorographic studies were made of me while I masticated a beef sandwich. The mandibular movements were observed from the very beginning of the process of mastication, when the bolus of food was thick, to the last few mandibular strokes, when the food between the teeth was reduced considerably and nearly ready for deglutition. This exposed to view

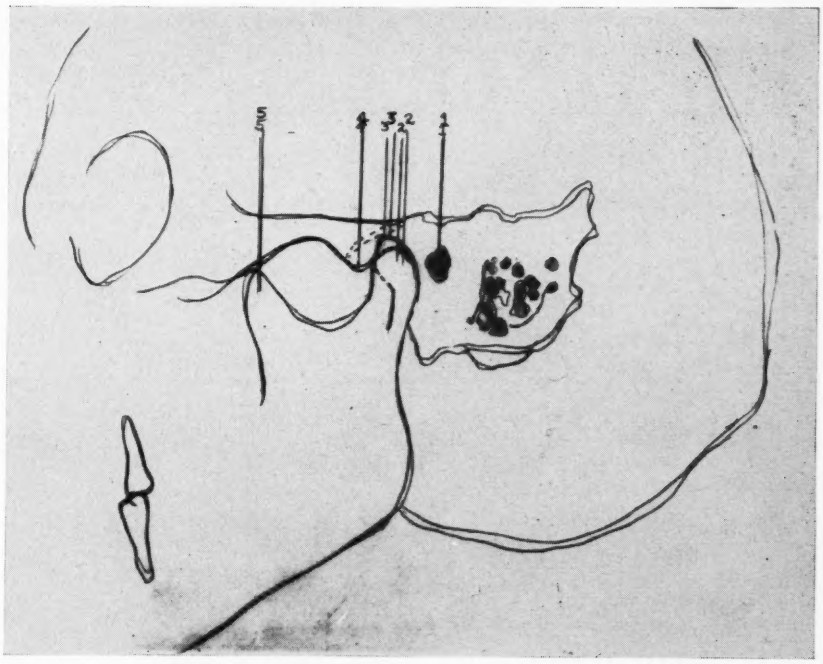

Fig. 17.—Superimposition of the tracing representing the right lateral working side occlusion, over the tracing representing the same structures with the teeth in centric occlusion, associated with centric jaw relation. There is no evidence of the slightest lateral shift of the mandibular condyle on the working side away from its articular surface. The vertical lines *2* and *3* do not coincide because they were placed there arbitrarily just to indicate the condyle and glenoid cavity in centric and lateral working occlusion, respectively. However, the condyles and glenoid cavities coincide in both instances.

the true physiologic movements of all constituent parts of the mandible. Yet, at no time between the initial and final stages of mastication on the bolus could any lateral gliding of the mandibular condyle on the working side (Bennett movement) be observed. However, cinefluorographic studies of physiologic lateral mandibular movements with the teeth in continuous contact suggest, if anything, a slight rotation of the condyle on the working side upward and backward. This rotation is effected in all probability by the combined action of the digastric, the deep fibers of the masseter, and the posterior fibers of the temporal muscle.

Fig. 18.

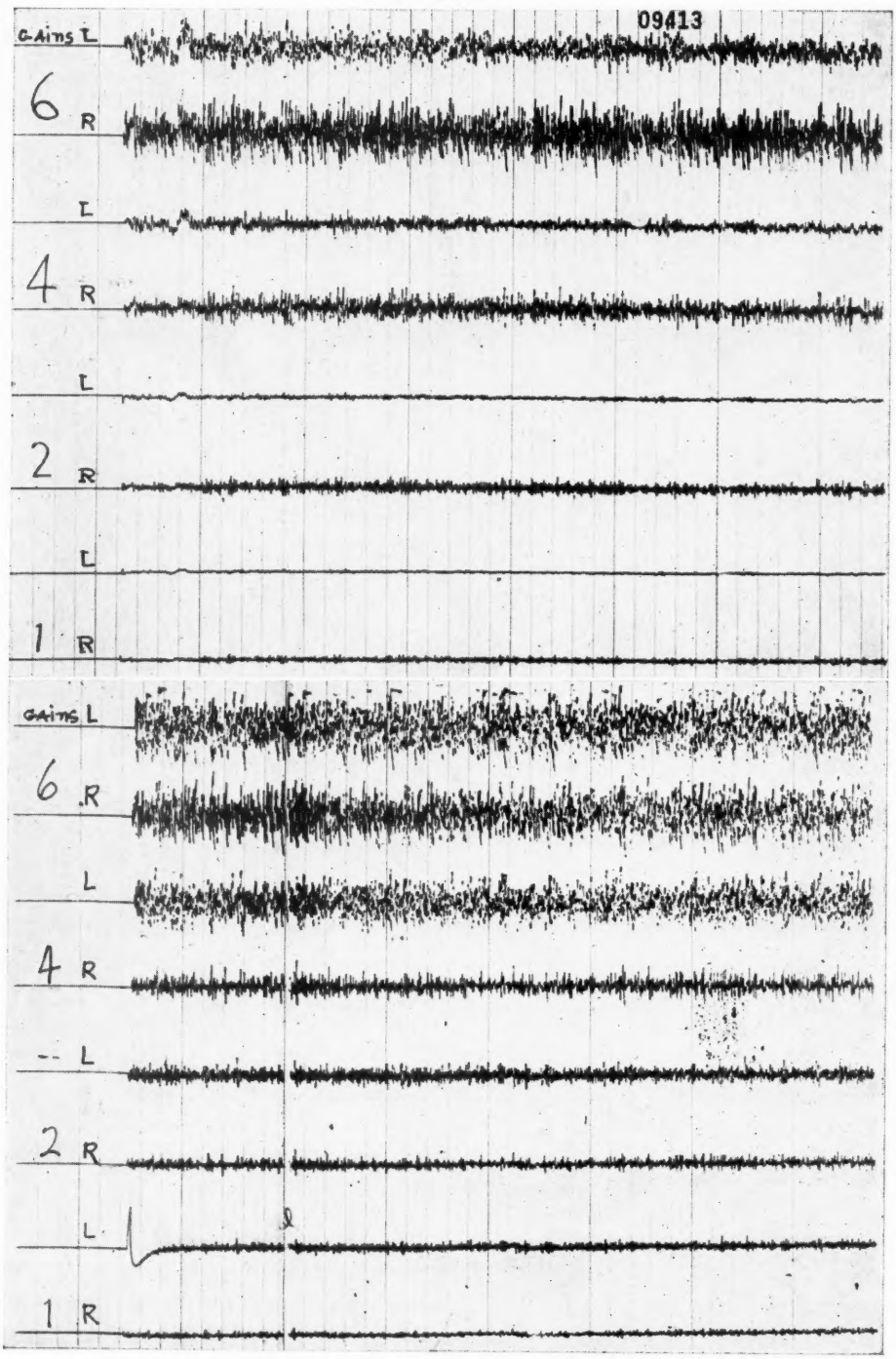

Fig. 19.

Figs. 18-19.—*(For legends see opposite page.)*

ELECTROMYOGRAPHIC STUDY OF THE BENNETT MOVEMENT

Impressions of my own dentition were made in an alginate impression material. Casts were poured and mounted in centric relation on an adjustable articulator by means of a face-bow. An intraoral centric jaw relation record was secured in soft wax on the articulator, and this record was checked carefully and corrected in the mouth. It was wrapped in tin foil and preserved as a permanent record. A lateral working position wax record was secured on the articulator and checked in the mouth. It also was preserved in tin foil as a permanent record. In both instances, the thickness of the wax between the teeth did not exceed 0.5 mm. to 1.0 mm.

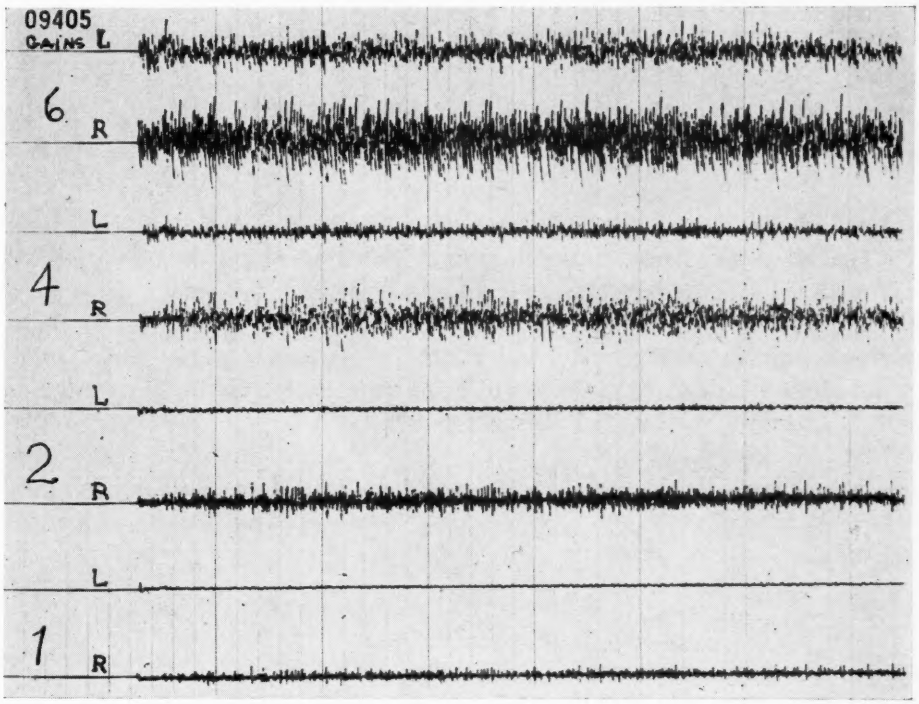

Fig. 20.—Right lateral horizontal fibers of temporal muscle. The electrical activity of the horizontal fibers of the temporal muscle in right lateral occlusion. In all gains, the right side contracts much more intensely than the left side.

Electromyographic studies were made with and without the intraoral wax records. A Grass eight-channel electroencephalograph was used with a 30 mm. paper speed. Skin electrodes were attached with Bentonite paste. Ground return

Fig. 18.—Right lateral central belly of temporal muscle. An electromyographic recording of the horizontal fibers of the temporal muscle when the mandible is in right lateral working occlusion. *L* and *R* denote, respectively, the left and right side. It is evident that the right side (*R*) contracts more intensely than the left side (*L*) in any one of the gains (6, 4, 2, 1).

Fig. 19.—Left lateral central belly of temporal muscle. Left lateral horizontal fibers of temporal muscle showing more intense electrical activity on the left side than on the right side. The electrodes were placed at the origin of the horizontal fibers of the temporal muscle. Here the left side contracts more intensely than the right side. However, the difference in the intensity is less pronounced than in the previous electromyogram (Fig. 18).

leads were attached to the ear lobes. The instrument was adjusted as follows: lead 1 and 2 at a gain of 6 microvolts, lead 3 and 4 at a gain of 4 microvolts, lead 5 and 6 at a gain of 2 microvolts, and lead 7 and 8 at a gain of 1 microvolt.

An oscillograph was used to check the data recorded by the ink writers on the electromyograms.

When the skin electrodes were attached to the areas of the origin of the horizontal fibers of the temporal muscles and electromyograms were obtained, it was found that the contraction of these fibers on the working side was more intense than the contraction of the corresponding fibers on the balancing side. This indicates that the mandibular condyle on the working side becomes the vertical axis of rotation for the lateral mandibular movement initiated by the contraction of the external pterygoid muscle of the opposite side.

If the "Bennett movement" were valid, the *horizontal fibers of the temporal muscle (an elevator muscle) on that side should not be expected to contract whatsoever. The fact that these fibers do contract shows that they rotate the working condyle around its vertical axis* (Figs. 18, 19, and 20).

SUMMARY

The validity of the "Bennett movement" must be seriously questioned when it is analyzed from a biologic and clinical viewpoint. The study of skulls and cadavers and the in vivo studies using roentgenographic, cinefluorographic, and electromyographic techniques fail to indicate the occurrence of the lateral shift of the mandible which is characteristic of a current concept of the "Bennett movement." The main evidence that Bennett presented in favor of his hypothesis was derived from his optical approach to the study of lateral mandibular movements. This will be considered, tested, and discussed in Part II of this analysis.

REFERENCE

1. Bennett, Norman G.: A Contribution to the Study of the Movements of the Mandible, Proceedings of Royal Society of Medicine, Section of Odontology **1**:79-95, 1908. (Reprinted J. Pros. Den. **8**:41-54, 1958.)

BOOK REVIEW

PARTIAL DENTURES. By Kenneth P. Austin, D.D.S., F.I.C.D., and Ernest F. Lidge, Jr., D.D.S., B.S., St. Louis, 1957, The C. V. Mosby Company. Pp. 227, illustrated, indexed. Price $9.50.

Partial Dentures—A Practical Textbook was written as a guide to the dental student or the practicing dentist who wishes to review the latest concepts and techniques in removable partial denture construction. The material is presented concisely and directly, using understandable terminology, and is presented from a very practical approach. The text is supplemented by 165 illustrations. The materials used in the book itself are of excellent quality.

The book is divided into five parts. The first two parts make up 173 pages while the last three parts total 41 pages.

Part I includes a simple method of classification of partial dentures, a complete description of both psychologic and physical aspects of patient examination, and a section on visual and digital examination. There are sections on surveying, designing, preparation of the mouth, the making of impressions, cast construction, and recording of jaw relations.

Part II is devoted mainly to the laboratory procedures in removable partial denture construction. This is a necessary section for both undergraduates and practicing dentists in that it is essential that they be completely familiar with those phases of construction which, in many instances, are being completed for them. Part II carries the partial denture construction through cast duplication, wax-up and casting of the framework, selection and setting of teeth, and flasking, packing, processing, and finishing.

Part III deals with the insertion of the completed partial denture and associated adjustments and with the correction of occlusion. There is a good section on patient education as it effects the success of the denture.

Part IV covers duplicating of denture base areas, relining and repairs, and stress-breaker partial dentures.

Part V is devoted to trouble-shooting. This section discusses problems that may arise in the completed denture and suggestions as to their corrections. There is an interesting discussion on the relationship that improper occlusion may have to symptoms arising in the body outside the oral cavity.

This book adequately covers its intended purposes and is recommended to dental students and practicing dentists.

Judson C. Hickey, D.D.S.

NEWS AND NOTES

MEETINGS

Pacific Coast Society of Prosthodontists, Timberline Lodge, Government Camp, Oregon, July 31 to Aug. 2, 1958.

International Dental Federation, Brussels, Belgium, Aug. 27 to Sept. 4, 1958. Dr. Marcel Joachim L.S.D., 67, rue de Trèves, Brussels, Belgium, will send all necessary information together with forms for registration and reservation of accommodation upon request.

Society of Odonto-Stomatologie and Maxillo-Facial Surgery, Pavia University, Pavia, Lombardy, Italy, Sept. 3 to 7, 1958.

Mid-Continent Dental Congress, Chase-Park Plaza Hotel, St. Louis, Mo., Oct. 12 to 15, 1958. For further information, contact the St. Louis Dental Society, 8013 Maryland Ave., St. Louis 5, Mo.

American Academy of Periodontology, Baker Hotel, Dallas, Texas, Nov. 6 to 8, 1958.

American Denture Society, Adolphus Hotel, Dallas, Texas, Nov. 7 and 8, 1958.

Greater New York Academy of Prosthodontics, School of Dental and Oral Surgery, Columbia University, New York, N. Y., Dec. 6 and 7, 1958.

Greater New York Dental Meeting, Statler Hotel, New York, N. Y., Dec. 8 to 12, 1958.

ANNOUNCEMENTS

Reprints of the "Glossary of Prosthodontic Terms" may be obtained by writing to Glossary Reprints, 400 Starks Bldg., Louisville, Ky. The price is fifty cents per copy. Please make your check or money order payable to Glossary Reprints and enclose, with your order.

Indiana University, School of Dentistry announces a course for technicians in Laboratory Phases of Fixed Bridge Construction, July 28 through Aug. 1, 1958.

The Complete Denture Section of the Detroit Dental Clinic Club announces the following seminar:

The Use of Neuromuscular Function in Denture Prosthesis, Aug. 6 to 10, 1958, Lake Paul Lodge, Hawks, Mich. This Conference seminar is open to members in good standing of the American Dental Association and its Foreign Affiliates. The seminar staff includes: Dr. Russell Wilford Tench, York, Pa., "Establishing Basic Pattern for Equilibrated Denture Design with Assistance of Neuro-muscular Function"; Dr. Joseph R. Jarabak, Loyola University, School of Dentistry, Chicago, Ill., "Anatomy and Physiology of Stomatognathic System"; and Dr. Andre Robert, Department of Endocrinology, Upjohn Co., Research Div., Kalamazoo, Mich., "Stress and the Adaptation Syndrome."

For further information and application, write to Dr. A. Alfred Nelson, 245 West Ten Mile Road, Royal Oak, Mich.

The University of Santo Domingo, College of Dentistry announces the following two courses to be given in conjunction with the University of Alabama School of Dentistry:

Prosthodontics, Dr. William L. McCracken, Aug. 4 to 8, 1958.

Oral Surgery, Dr. Rene A. Puig Bentz, Sept. 1 to 5, 1958.

For further information, write to Dr. Fernando Camino Cestero, Dean, University of Santo Domingo, College of Dentistry, Ciudad Trujillo, Dominican Republic.

The Loyola University School of Dentistry's Department of Periodontology will present a two-week course in "Theory and Practice of Periodontics" to be given at the Department of Dentistry at Michael Reese Hospital in Chicago, Sept. 16 to 27, 1958.

For further information and application write to the Dental Department, Michael Reese Hospital, 29th Street and Ellis Avenue, Chicago 16, Ill.

The University of Pennsylvania, School of Dentistry, announces the following postgraduate course:

Endodontics Teachers' Course, Dr. Louis I. Grossman and Associates, Sept. 8 to 10, 1958.

For further information or application, write to Director, Postgraduate Courses, School of Dentistry, University of Pennsylvania, 4001 Spruce St., Philadelphia 4, Pa.

The University of Alabama School of Dentistry announces the following refresher course:

Hypnosis Applied to Dentistry, Dr. William T. Heron, Sept. 20 to 22, 1958.

For further information, write to the Director, Refresher Course Program, University of Alabama School of Dentistry, 1919 7th Ave., S., Birmingham, Ala.

Tufts University School of Dental Medicine announces the following postgraduate refresher course:

A Special Participation Course in Periodontology, Dr. Irving Glickman and Staff, Oct. 6 to 10, 1958.

For further information and application, write to Director of Graduate and Postgraduate Studies, Tufts University School of Dental Medicine, 136 Harrison Ave., Boston, Mass.

Dr. Raymond J. Nagle, Dean of the New York University College of Dentistry, received the Sigma Epsilon Delta National Honorary award on May 14, 1958, at the Concord Hotel in Kiamesha Lake, N. Y. This award is made annually to an outstanding person in dentistry or an allied profession.

The Chicago Dental Society announces its annual prize of $500.00 for the most meritorious essay of an original investigation containing new and significant material of value to dentistry.

Application to enter the competition must be filed in the office of the Society before Sept. 1, 1958. This form, as well as complete contest rules, may be secured by writing to the Chicago Dental Society, 30 North Michigan Avenue, Chicago 2, Ill.

DIRECTORY

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